

SHARK ATTACK

IN JANUARY 1981, AN ISRAELI freighter sank in the notorious waters of the Bermuda Triangle. As the crew floundered in the tropical waters, one of them thought he saw a family of large fish swimming towards them. Twenty-five of the sailors died and rescuers reported having to drag mutilated bodies from the jaws of the army of vicious sharks.

Cold, deliberate and persistent in its quest for food, the great white shark will eat just about anything to satisfy its enormous appetite. Sea lions, sea otters, fish and dolphins have been recovered from a dead shark's stomach. The great white hunts singly or in packs.

All its senses are finely tuned to the pursuit of prey. It has an excel-

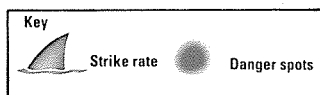
lent sense of smell, good eyesight and it can even detect the faintest electrical and pressure fields coming from its quarry. Once the target has been selected, the shark, in a sudden burst of speed, lunges towards its victim. Its snout bends upwards so that the mouth moves forward, jaws gaping wide. On inflicting the first lashing wound, the shark will often retreat briefly before returning for the kill.

Ocean giants

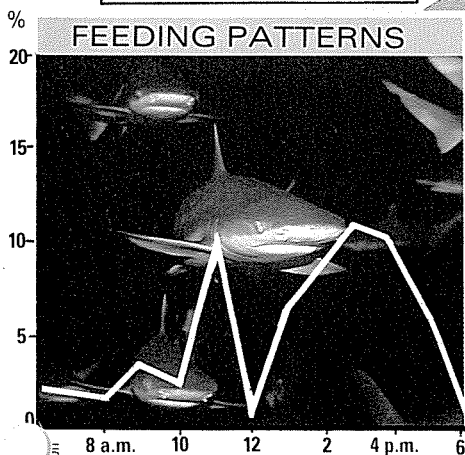
Most great whites grow to 4.5 metres in length, but some larger specimens have been caught. The females are bigger than the males, and a 6.4 metre long female caught off the coast of Cuba tipped the scales at 3,312 kg – the heaviest weight recorded for a great white. In circumference, she measured an

The formidable jaws of the great white shark.

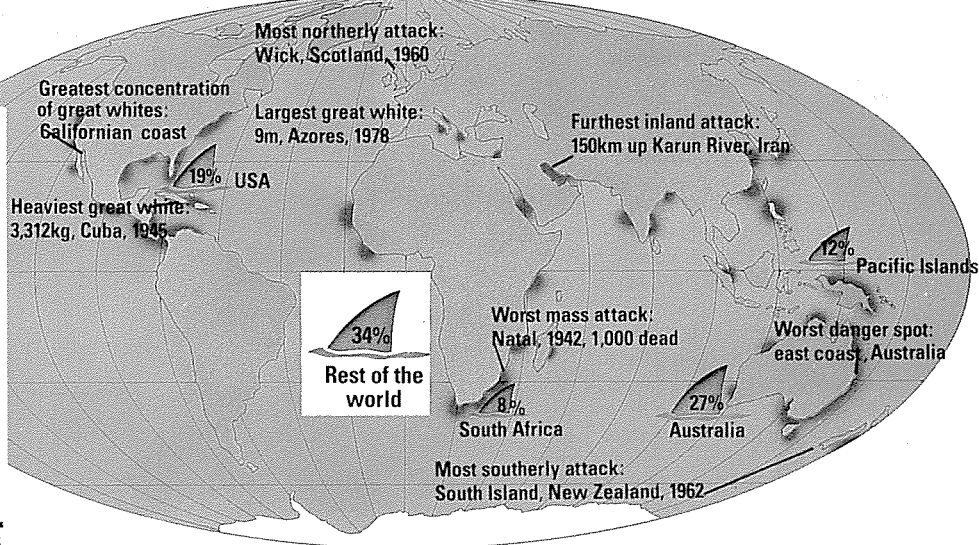
ATTACKS WORLDWIDE



FEEDING PATTERNS



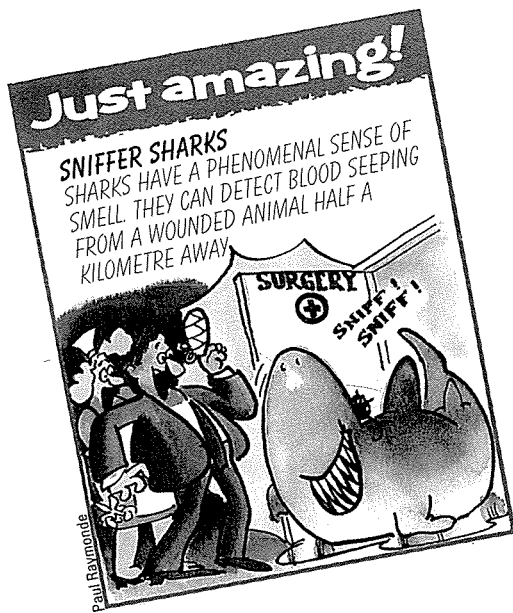
The graph shows the percentage of attacks at various times. Whether they reflect sharks' dietary patterns, or bathers' swimming times is unknown.



The majority of shark attacks occur where ocean bathing is a popular pastime. Thirty per cent of attacks worldwide are fatal. Surprisingly, this

figure rises to 60 per cent in European waters. There is an average of 28 documented attacks yearly, but estimates put the number nearer to 100.





astonishing 4.5 metres and was beached only with the aid of several trucks. Some of the great whites that got away have been estimated at more than 11 metres in length, which is almost as long as a double decker bus.

Unfair reputation

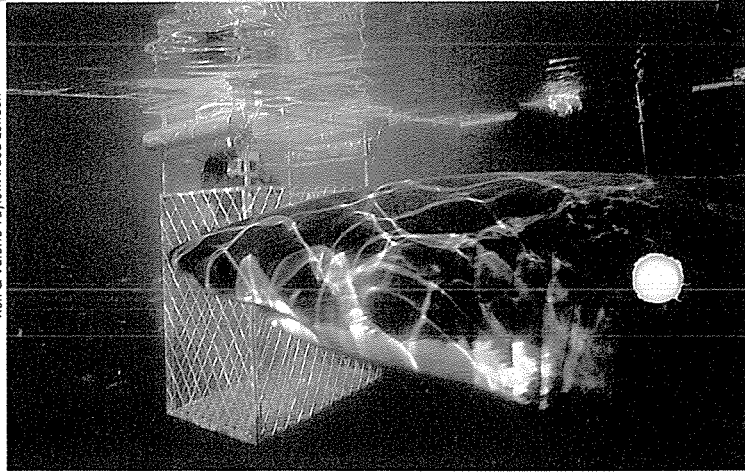
Sharks have been around on Earth for 400 million years, with the earliest species growing to immense lengths of up to 30 metres – now recorded only as fossils. Their descendants have become a diverse group of creatures with only a few of the 344 species conforming to the image of the fierce maneater.

Apart from the great white, the two most deadly are the tiger shark and the bull shark – the latter is known to swim up rivers and attack its victims.

Because of its reputation as a

Photographing the world's largest maneater is not a task for the faint-hearted. With its serrated teeth and powerful jaws, the great white is quite capable of ripping a steel cage open.

Ron & Valerie Taylor/Ardea London



I SURVIVED AN ATTACK

Spearfishing off the Great Barrier Reef, Rodney Fox was attacked by a great white. 'It was like being hit by a train,' said Fox. After surging through the water at high speed, gripped in the powerful jaws of the shark, Fox struggled free, but his injuries required 462 stitches.



Ron & Valerie Taylor/Ardea London

maneater, there has been little scientific research on the great white. However, we do know that, like all sharks, their skeletons are made of cartilage – a tough flexible tissue – rather than bone.

They mate in the same way as many mammals. The male introduces sperm into the female's reproductive tract with his claspers. Some sharks – the great white included – give birth to live young, with up to 100 pups per litter. Others, like the whale shark, lay eggs. In some species, the babies are cannibalistic while still inside the mother – they eat their brothers and sisters before they are born.

Found in almost every ocean in the world, great whites tend to be territorial, returning to the same feeding ground every year.

Death of the hunter

The great white's reputation as the largest potentially lethal creature in the ocean could soon be toppled. Man, its greatest enemy, stalks the shark – and without protection the great white is in danger of being hunted to extinction.

SHARK SPOTTER

1 Tiger shark: eats hammerheads, turtles and garbage; maneater. Favours warm oceans.

2 Whale shark: biggest fish; largest caught: 12.65 m, Karachi Pakistan. Skin is a record 10 cm thick.

3 Megamouth shark: enormous luminous mouth. Only three specimens ever caught – first discovered in 1976 off Hawaii.

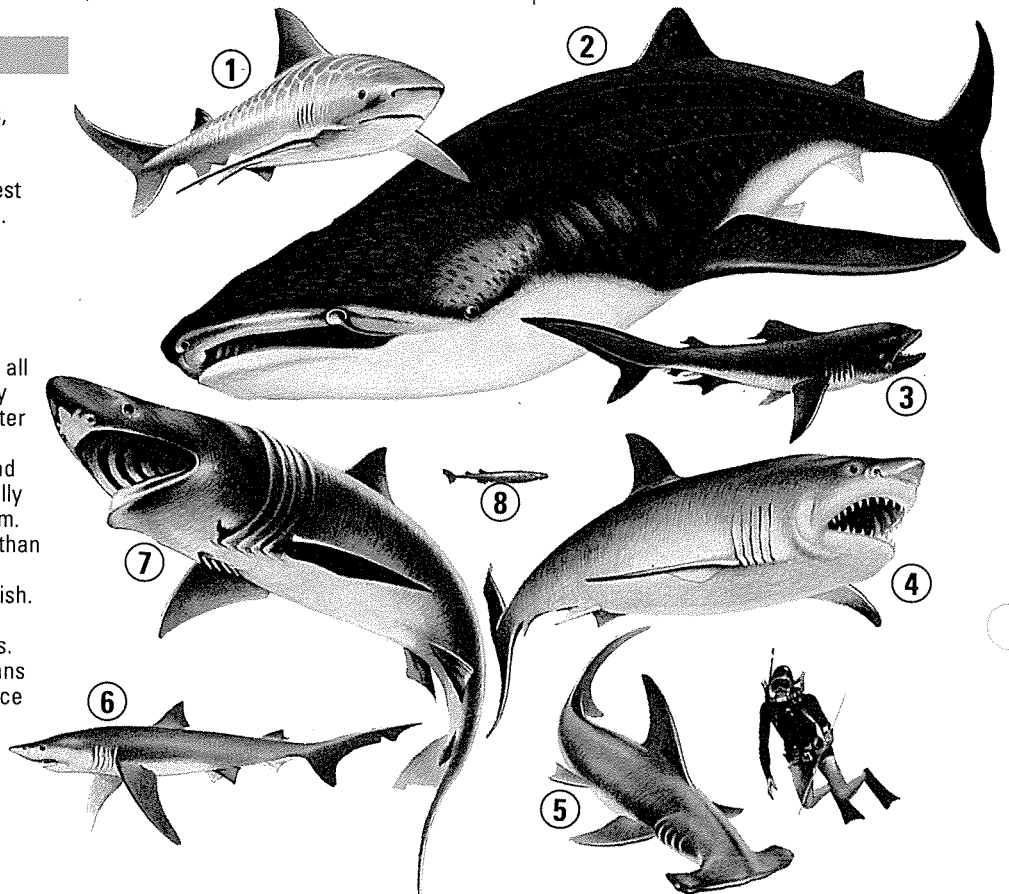
4 Great white: maneater, found in all warm seas and shallow bays. Only shark to lift its head above the water to view objects on the surface.

5 Hammerhead: oddly shaped head with nostril on each side. Potentially dangerous to man. Max length: 7 m.

6 Blue shark: found in more seas than any other shark. Max length: 4 m.

7 Basking shark: second largest fish. Enormous liver enables it to float. Filter feeder, found in most oceans.

8 Cookiecutter: lives in deep oceans and travels up to 7 km to the surface to feed, by tearing lumps out of whales, squid and large fish. Length: a mere 50 cm.



THE GOOD

THE BAD

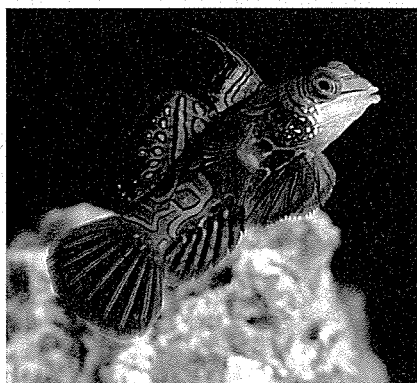
THE UGLY

WONDERS

OVER 80 PER CENT OF LIFE ON Earth inhabits the oceans. There are almost 30,000 different species of fish and over 100,000 other varieties of marine creatures, from deadly octopuses to giant worms.

Each year, about a hundred previously unknown sea creatures are discovered in the sea.

Perfectly adapted to their environment, fish are masters of disguise. For example, the bright colours of coral reef fish may help them to blend in with the brilliant background. Along rocky shores the fish are often stone coloured. By contrast, as far as 10 km under the surface, the inhabitants have luminous lures to attract their prey in a region where no light ever reaches.

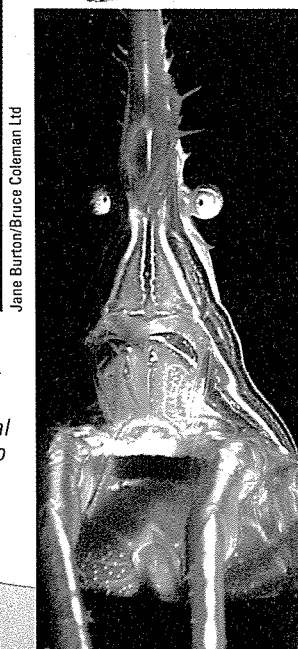


Jane Burton/Bruce Coleman Ltd

Black swallower (top right). Dwells in the deeps and can eat prey larger than itself.

Mandarin fish (above). Territorial creatures, two males will fight to the death.

Arrowhead crabs (right). Elongated so they can squeeze between rocks to hide.

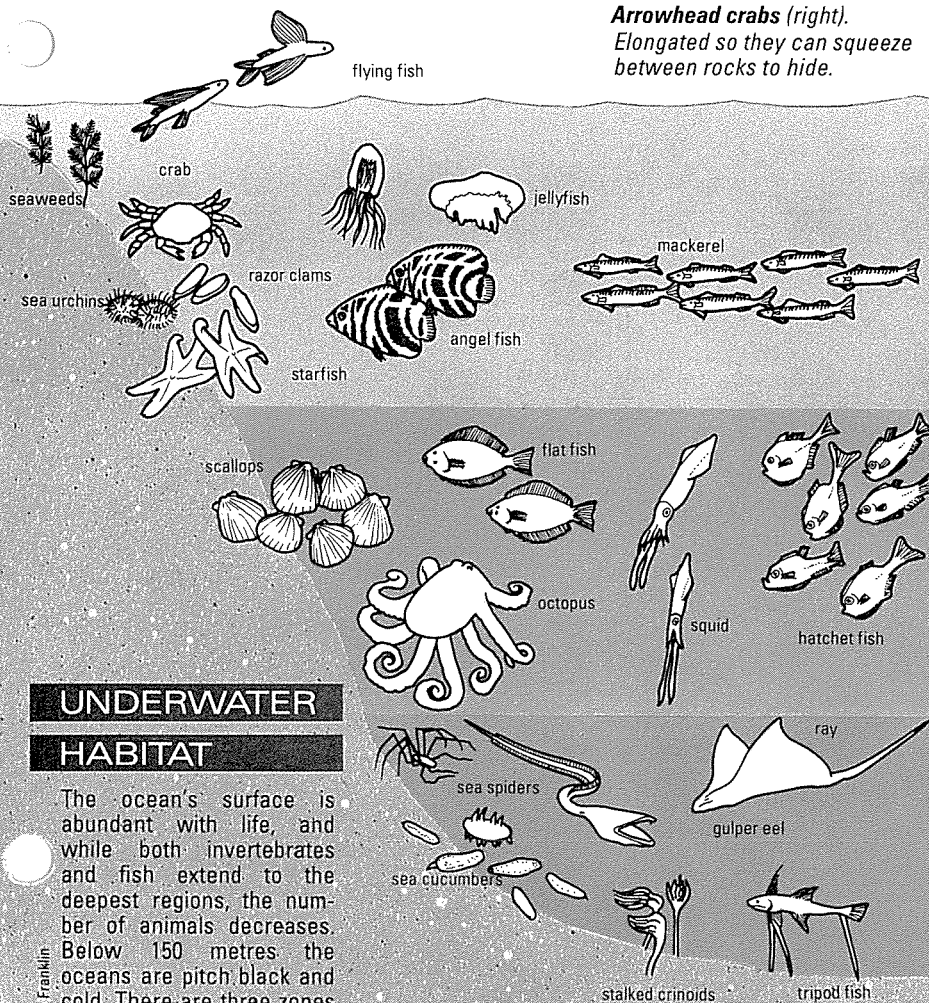


Warren Williams/Planet Earth Pictures

Sunlit zone 0–199 m. Average temperature 16°C. The most densely populated part of the ocean. Minute plants flourish and are the basic food for a variety of animals.

Twilight zone 200–999 m. Average temperature 10°C. The animals are often brilliant reds and have enormous eyes to see in the darkness. Many fish have glowing organs to entice both mates and prey. Squid squirt a luminescent ink to divert would-be attackers.

Bathypelagic (sunless) zone 1–10 km. Average temperature 3°C. Creatures have small eyes as they rely mainly on sound and smell to detect prey. Often grotesque, their shape has adapted to the conditions, particularly to catching what food there is at this depth.



UNDERWATER

HABITAT

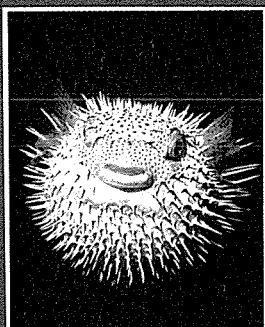
The ocean's surface is abundant with life, and while both invertebrates and fish extend to the deepest regions, the number of animals decreases. Below 150 metres the oceans are pitch black and cold. There are three zones (see right).





VIEW BIZARRE SEA CREATURES

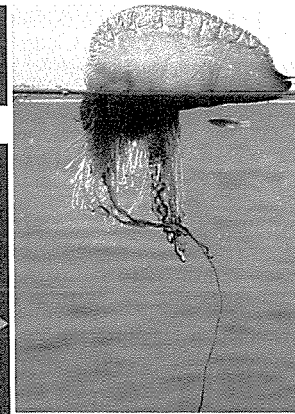
PEP/Christian Petron



Puffer fish. Inflates its body and spines when threatened. A delicacy in Japan, some parts of the fish are poisonous and, if eaten by mistake, could cause death in minutes.

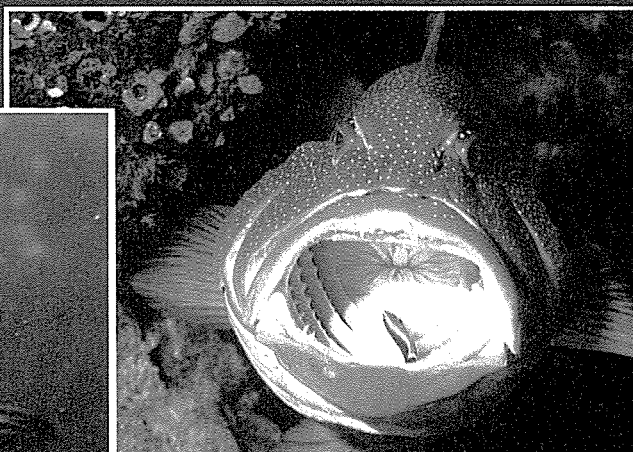
Portuguese Man O'War. Has a blue gas-filled float. Filaments with stinging organs trail as far as 20 metres below the surface to catch and stun its prey before devouring it.

PEP/Flip Schulte



PEP/Bill Wood

Cleaner wrasse. The ocean dentist feeds by sucking parasites from inside the mouth of larger fish. When finished, the wrasse may exit through the gills of his host.



Valerie Taylor/Ardea London

Harlequin Tusk fish. Brightly coloured to warn other fish of the same species to keep off its territory. Any invaders risk a vicious battle.

Seahorse. The male bears the children. The mother deposits the eggs in an opening located under the male's tail. The father fertilizes and incubates the eggs until he gives birth about 10 days later. He often eats a few of the 100 or more babies.

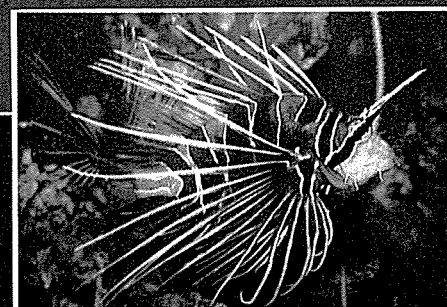
P. Morris/Ardea London



Jon Kentfield/Bruce Coleman Ltd



Stonefish. The most venomous fish in the ocean. Lying on shallow rocks, it can be fatal to the unwary swimmer.

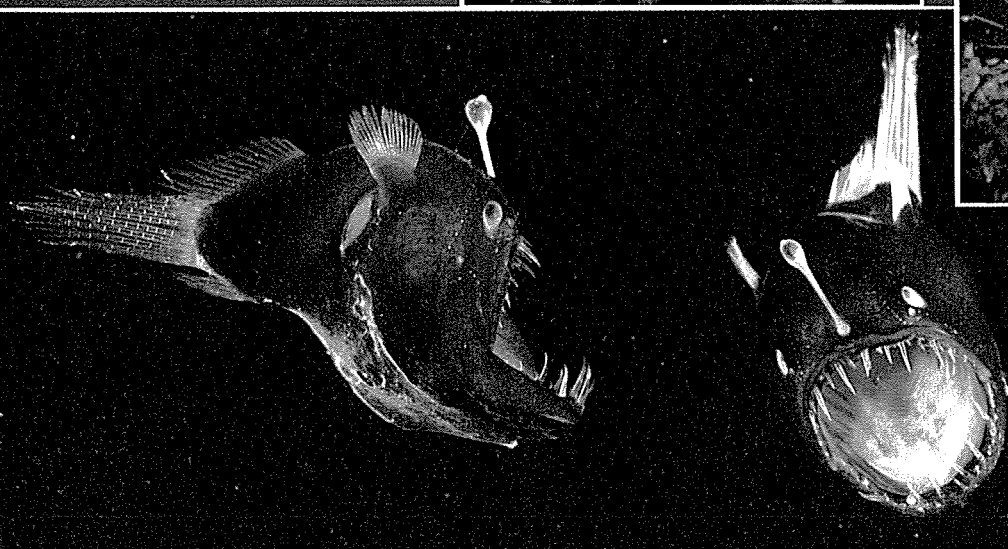


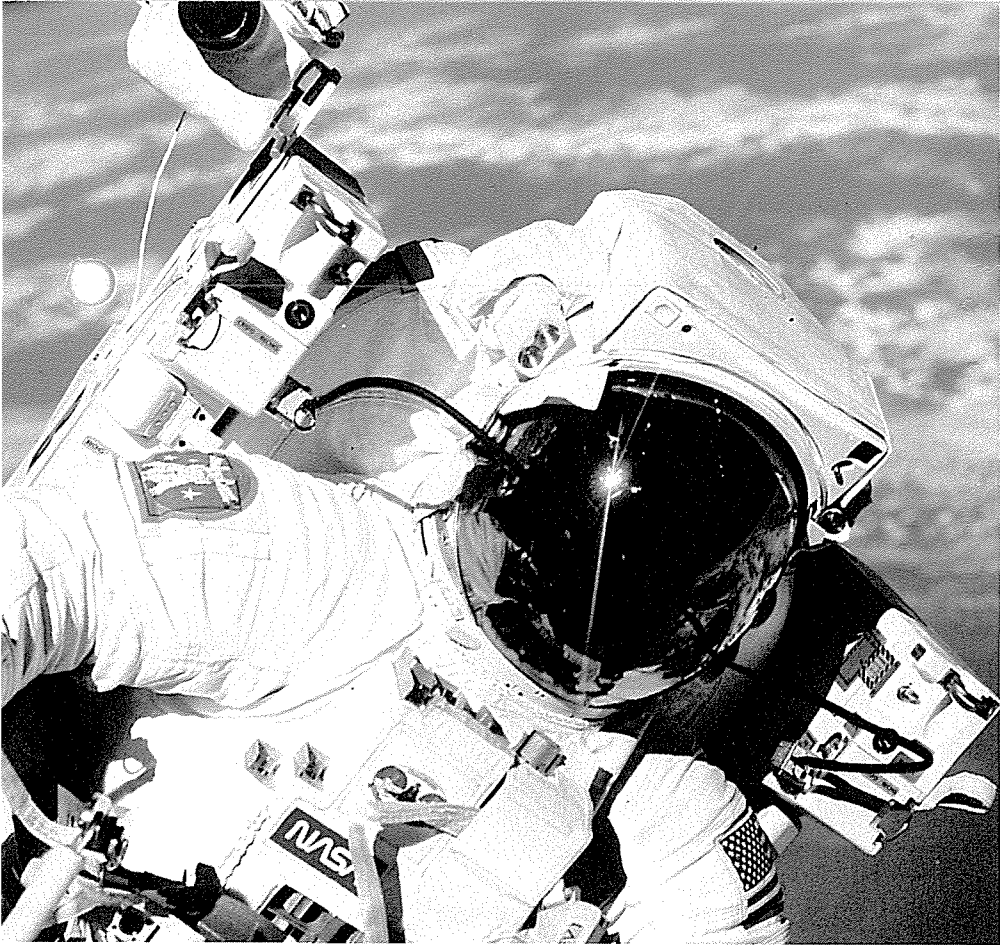
Ale Lindau/Ardea London

PEP/Peter David

Lionfish. Poisonous spines warn predators to steer clear. The poison is more deadly than cobra venom and causes serious injury, or death.

Female angler fish. A luminous lure on her head attracts prey into her jaws. Growing up to a metre long, the female often has parasitic males living off her blood supply.





Going walkabout in space, American astronaut Bruce McCandless is encased in what is virtually a portable life support system. It protects him from harmful radiation and extremes of temperature, and also supplies vital air and air pressure.

a minute, the passengers float around inside the plane, bouncing off specially padded walls.

● Staying healthy in space

Observations on Russian and American astronauts who have spent several months in orbit have already pointed out some of the dangers of long space journeys. In zero gravity, the heart grows weaker and steadily shrinks. Muscles lose their tone and gradually waste away. But most worrying of all is the effect that weightlessness has on an astronaut's skeleton.

On Earth, our bones completely renew themselves about every six months or so. In zero gravity, however, while the calcium in an astronaut's bones disappears at the same rate as it does on Earth, new bone growth dramatically slows down. The result is that, over time, the space traveller's skeleton becomes more and more brittle. Scientists are still not sure if this defect can be completely reversed once the astronaut returns to Earth.

● On the go

One way astronauts can combat some of the problems of weightlessness is by exercising for several hours a day while they are in space. A small gymnasium, with jogging machine and exercise bike, will be essential on any future permanently manned space station or interplanetary spaceship. And it would be better still if the astronauts' living and working areas could be arranged to spin slowly around so as to provide a force similar to that of gravity.

SURVIVING IN SPACE

- TOUGH TRAINING
- BEATING GRAVITY
- BRITTLE BONES

UNDER 40 YEARS OF AGE, less than 173 cm tall, excellent health, an engineering degree as well as long experience as an expert jet pilot.

These were just some of the requirements for the USA's first astronauts. Today, the qualifications are much less strict. Even so, would-be astronauts must undergo a long and rigorous training programme.

Least popular of the devices a future space-traveller has to endure is the centrifuge. This whirls the astronaut around at an uncomfortably high speed to create the kind of stresses, known as *g*-forces, that will be experienced during lift-off and re-entry.

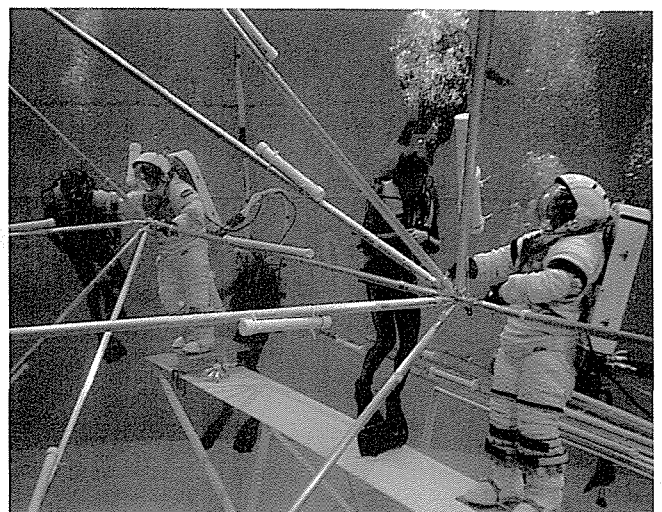
● Practising for zero-*g*

Once in space, the problem of high gravity is quickly replaced by that of zero-gravity, or weightlessness. Learning to cope with this strange

new condition is essential if an astronaut is to carry out tasks effectively.

Since Earth's gravity cannot simply be switched off, various ways have been found to simulate weightlessness without actually going into space. One of these is for an aircraft with trainee astronauts on board to dive along a special curving path. The effect is like that in a rapidly falling lift. For about half

An astronaut in water feels an effect similar to the weightlessness experienced in space. Wearing a spacesuit, fitted with weights so that he floats at a certain depth, he goes through the many routines he would use in space. Expert divers are on hand in case of an emergency.



MacDonnell Douglas





VIEW AN ASTRONAUT'S DAY



Before launching into space, astronauts must go through many hours of simulated flight. Robert Crippen practises at the controls in the cabin of the Space Shuttle orbiter, Columbia, at the Kennedy Space Center. Although the system is fully automated, complete familiarity prior to launch is vital.

On the inside looking out, Kathryn Sullivan views Earth from above. Women astronauts have been on several successful missions into space.



Catch your juice. Liquids do not pour in space but turn into globules. Drinks on board a spacecraft are sucked straight from their packs.

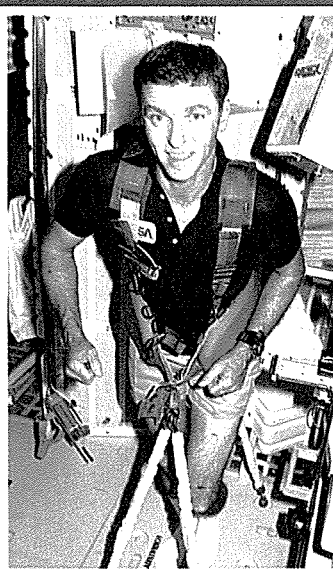
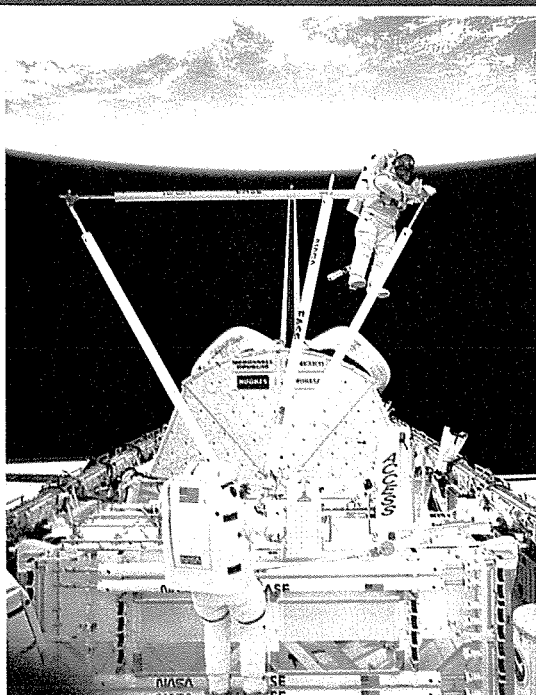
Come and get it! Steak, scrambled egg and strawberry cereal are some of the many foods taken into space. Most are freeze dried - water is added before eating. Everything is kept firmly in its place in sealed packs fixed to trays with tape to prevent them floating away.



Tied up for a while, two astronauts grab some sleep. As there is zero gravity in space, they have to be tethered down, and zoned into special sleeping suits to avoid floating off around the spacecraft.



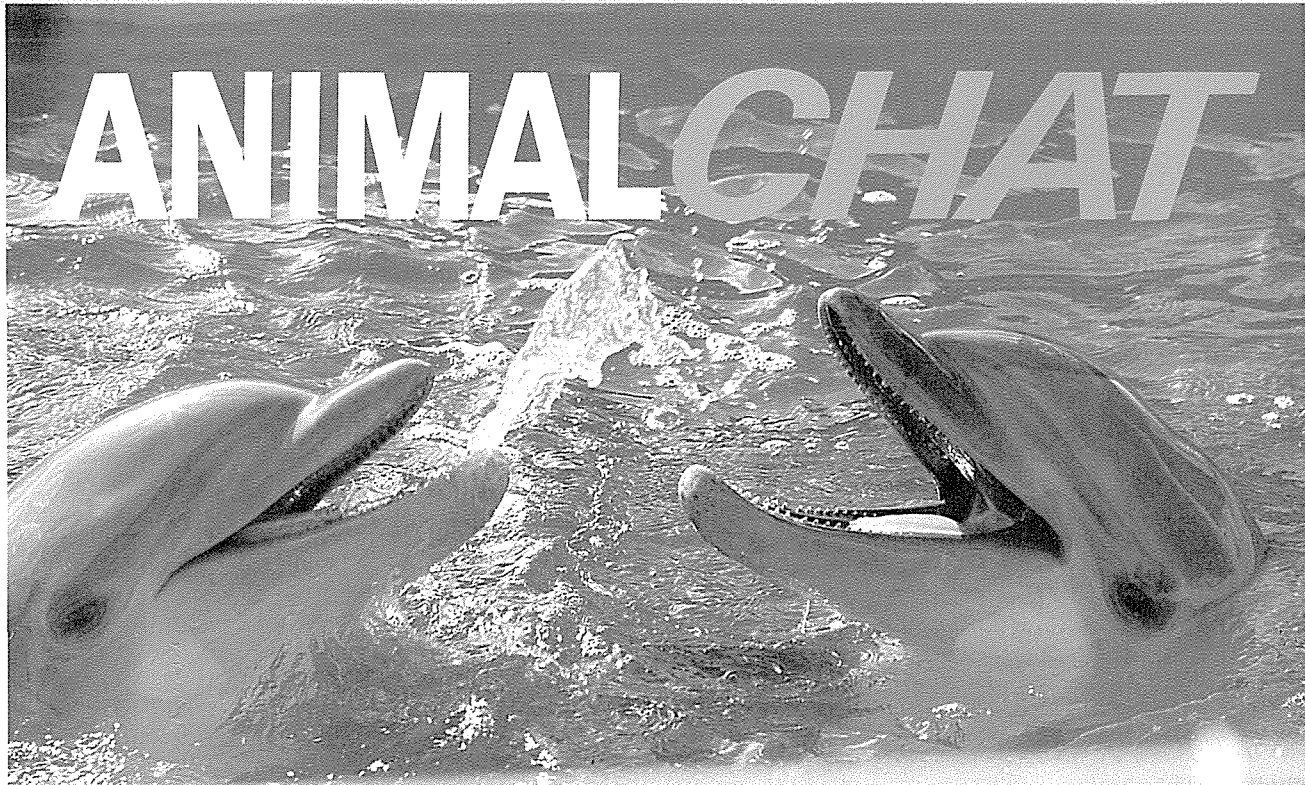
Like trapeze artists, two astronauts rise above the payload area of the Shuttle, then feet still attached by a wire to the spacecraft. Astronauts carry out many tasks in space including maintaining and repairing the spacecraft and satellites.



The daily grind 226 km above Earth. Astronauts must exercise regularly while in space to combat weakening of bones caused by lack of gravity. Joe Engle works harnessed to a special treadmill located in the mid-deck of the Shuttle.



ANIMAL CHAT



Zefa

TALKING DOLPHINS

TRAINING CHIMPS

SINGING WHALES

HUMAN BEINGS ARE NOT THE only ones who like to talk to each other. The animal world is filled with species who have their own special language.

Honeybees, for instance, are able to communicate with one another using dance language. When a foraging worker bee has found some flowers containing nectar, it flies back to its hive and begins one of two kinds of dance. The rest of the swarm gathers around to watch the performance, which takes place on the surface of the honeycomb.

A 'round' dance by the returning bee tells the onlookers that the flowers are less than 100 metres away. A 'waggle' dance shows not only that the nectar is further afield — the slower the dance the greater the distance — but also its direction from the hive.

Animals with bigger brains, especially mammals, tend to 'talk' to one another in even more elaborate ways. The squirrel-like prairie dog, which lives on the plains of North America, has a variety of calls. Rearing up on its hind legs and pointing

Dolphins have been known to imitate single words of human speech, but their pronunciation is so indistinct and their delivery so rapid, that only a trained ear can understand what they are saying.

its nose skyward, it utters a series of two-syllable sounds to make known the territory of its own group. If some enemy approaches it can let out instead a high-pitched alarm that warns its companions to scamper underground.

Almost human

Closest of all our animal relatives are the chimpanzee and the gorilla. So, it is hardly surprising that these two African great apes should communicate in ways that often seem very human. A rich combination of sounds and gestures make up chimp and gorilla language. The big question has always been whether an ape and a person could ever carry on a conversation.

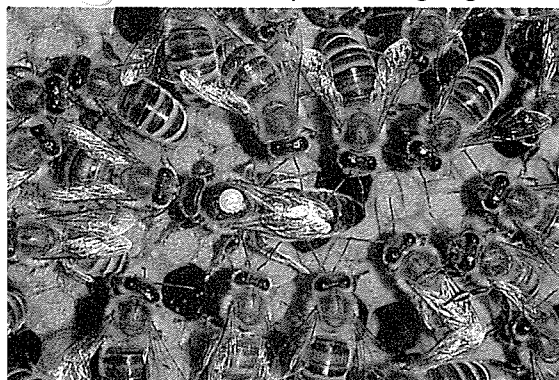
That question was answered in the late 1960s, when two American scientists hit upon an ingenious idea. Because apes are physically unable to speak like people, these scientists taught a young chimp,

Honeybees guide themselves by the position of the sun. The worker bees communicate the direction of a good food source by means of a dance performed in the hive.

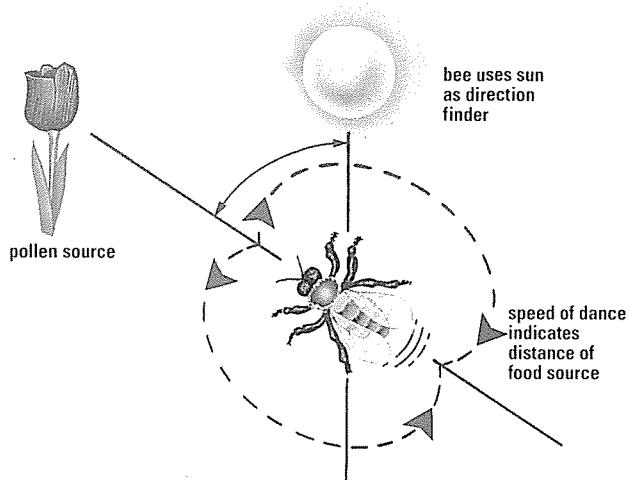
Chimpanzees can achieve surprising powers of communication if raised by humans. One chimp learned to say 'mama', 'papa' and 'cup', and used these words correctly most of the time.



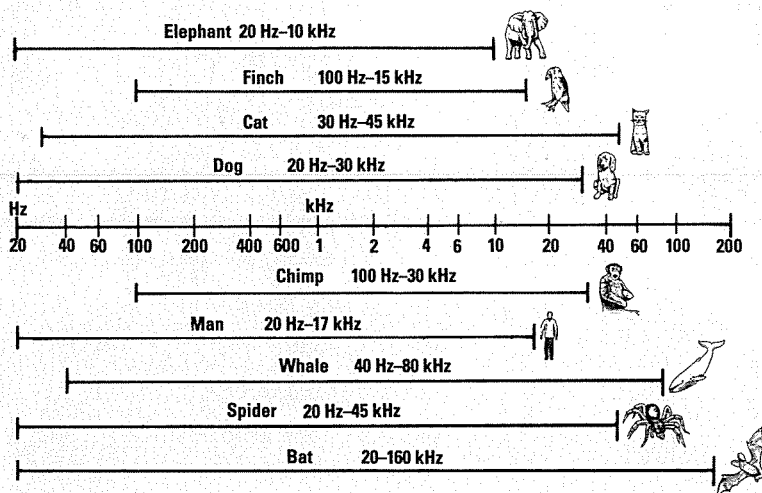
Rex Features



Mark Franklin/Bruce Coleman Ltd



TUNING INTO ANIMAL FREQUENCIES



Hearing is a vital part of animal communication, especially over long distances. The range, which varies considerably from species to species, is measured as sound frequency or the number of vibrations each sound makes per second in hertz (Hz) or kilohertz (kHz [1,000 Hz]). Hunters like cats and dogs, tend to be tuned into the high-pitched squeaks of mice and other prey – the 'silent' dog whistle works on ultrasonic frequencies, which are far too high for us to hear. Echolocators such as bats and whales use even higher ultrasonic sounds to make long distance calls.

Just as with humans, the hearing range of many animals diminishes as the individual grows older, often putting them at risk from predators.

Mark Franklin

called Washoe, how to use deaf-and-dumb sign language. Quickly, Washoe mastered the hand signals for several dozen objects, actions and feelings.

More recently, a pygmy chimpanzee, named Kanzi, has shown an even greater understanding of human language. Most of the time, Kanzi 'talks' with his keepers at a research centre in America by punching special symbols marked on a keyboard. But the little chimp has also shown that he can understand spoken English. If asked, for instance, 'Will you go and get a nappy for your sister Mulika?', he will do it.

On one occasion, a fellow chimp of Kanzi's, called Austin, was moved into another compound. For a while Kanzi seemed to miss his usual bedtime visit with his friend. But after several lonely nights he solved the problem by typing the symbols 'Austin' and 'TV' on his keyboard. When a videotape of Austin was played, Kanzi settled happily into his nest for the night.

Dolphins and whales may not look much like people, but their

large brains and complex patterns of behaviour suggest that they are very intelligent creatures. They also seem to have a sophisticated language for communicating with each other, made up of clicks, whistles and strangely beautiful songs.

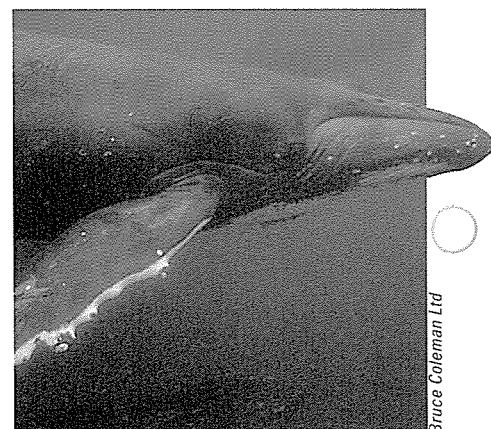
Songs of the sea

One of the great unsolved mysteries of the natural world concerns the songs of the humpback whale. At the start of each breeding season, all the male humpbacks sing the same complicated song that may go on for half an hour at a stretch. The sounds are so loud they can be heard underwater as far as 5 km away! Gradually, as the breeding season progresses, the song of all the humpbacks changes. By the end of the season, the song has become completely different.

When breeding time comes around again, the male humpbacks congregate once more and go through the whole process again.

No one knows why the humpbacks sing – or why their song changes each year. Using recording

apparatus and computers, scientists have analyzed the amazing variety of sounds that whales and dolphins make. They hope, one day, to decipher some of the language of these creatures and try to communicate with them.



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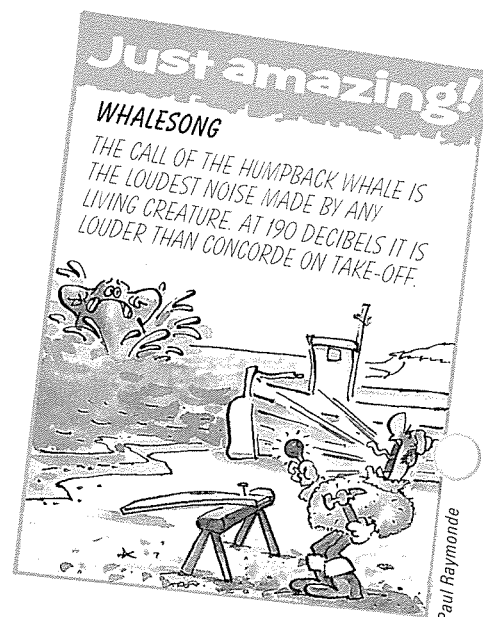
Courting humpbacks
communicate by exchanging playful blows. Though meant to be tender, the blows can be heard for miles.

CHEMICAL MESSAGES



Partridge Productions Ltd/OSF

Chemical substances called pheromones, secreted by the ants, are the prime means of communication within the colony. Worker ants tending the queen constantly lick her and gather together the pheromones she produces. The workers quickly circulate these to the other ants. Soldier ants also produce pheromones, and when the number of soldiers in the colony falls the queen – aware of the drop in the amount of soldier pheromones – produces special eggs destined to be soldiers.



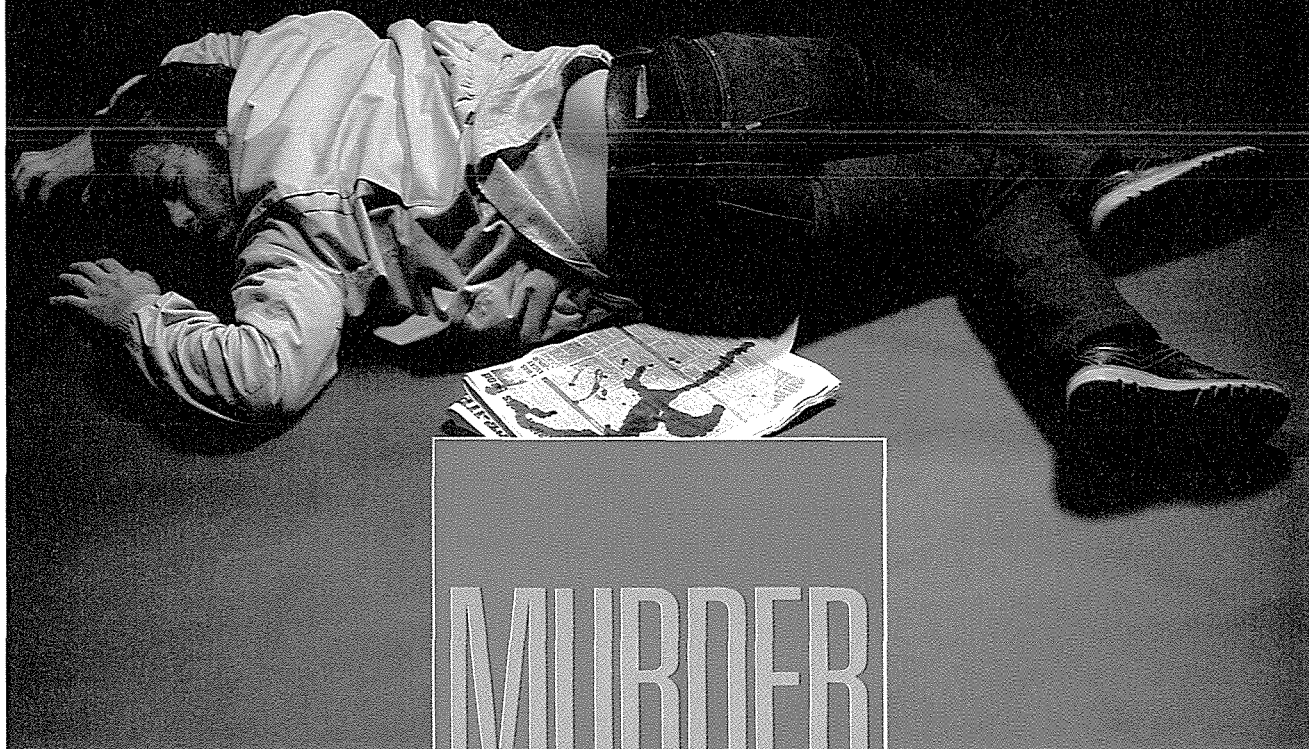
Paul Raymond



CAUSE OF DEATH

ANALYZING THE CLUES

THE POST MORTEM



MURDER ONE

ESTABLISHING THE
CAUSE OF
DEATH

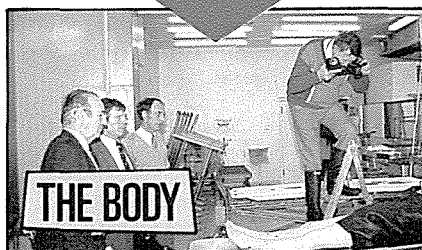
DR. HAWLEY HARVEY CRIPPEN, the notorious wife killer, mass poisoner Graham Young, John Haigh, who immersed his victims' bodies in baths of acid – these and many other murderers were unmasked by the police department's team of medical scientists.

Pathologists, toxicologists and dentists join together to find conclusive evidence from a single hair, a few fibres of cloth, a speck of dust or even teethmarks in an apple.

Once a body has been discovered the police are immediately faced with several questions – what is the victim's name and background? What could have caused the wound? Did it cause the victim's death? At what time did the victim die? Was the victim's death an accident, suicide or murder?

When the police have checked the scene of the crime for clues, it is up to medical science to examine the evidence and provide the police with the vital clues that may lead to

At the scene of the crime, a pathologist examines the body for wounds and bruising. The body temperature is taken to estimate time of death.



THE BODY

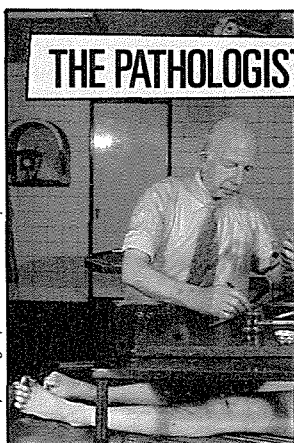
The body is then sent to the mortuary, under the supervision of the pathologist.

The police inform a police surgeon and the criminal investigation unit of the coroner's office, who then inform the coroner.

THE CORONER

The coroner, in consultation with a senior police officer, arranges for a post-mortem to be carried out.

THE PATHOLOGIST



The post-mortem is conducted at the mortuary, by a pathologist of their choice.

THE POST-MORTEM

The findings of the pathologist are relayed to the coroner who then arranges for an inquest.

THE INQUEST

The findings of the inquest may lead to criminal proceedings, after which the body is released for disposal.



WHEN DID HE DIE?

Monday - midnight

12:00 1

Muscles relax immediately and brain starts to liquefy.

Tuesday - am

5:00 1

Skin begins to discolour due to draining of blood.

Tuesday - noon

12:00 1

Rigor mortis complete. Body temperature now down to about 25°C.

Wednesday - noon

12:00 2

Rigor mortis has now disappeared altogether due to decomposition.

Thursday - noon

12:00 3

The next stage of putrefaction: marbling of veins due to gases.

Tuesday - am

12:10 1

Eyes begin to cloud over not long afterwards.

Tuesday - am

6:00 1

Rigor mortis (the stiffening of muscle) begins in the face.

Tuesday - midnight

12:00 2

Body temperature now same as surroundings. Decomposition begins.

Wednesday - midnight

12:00 2

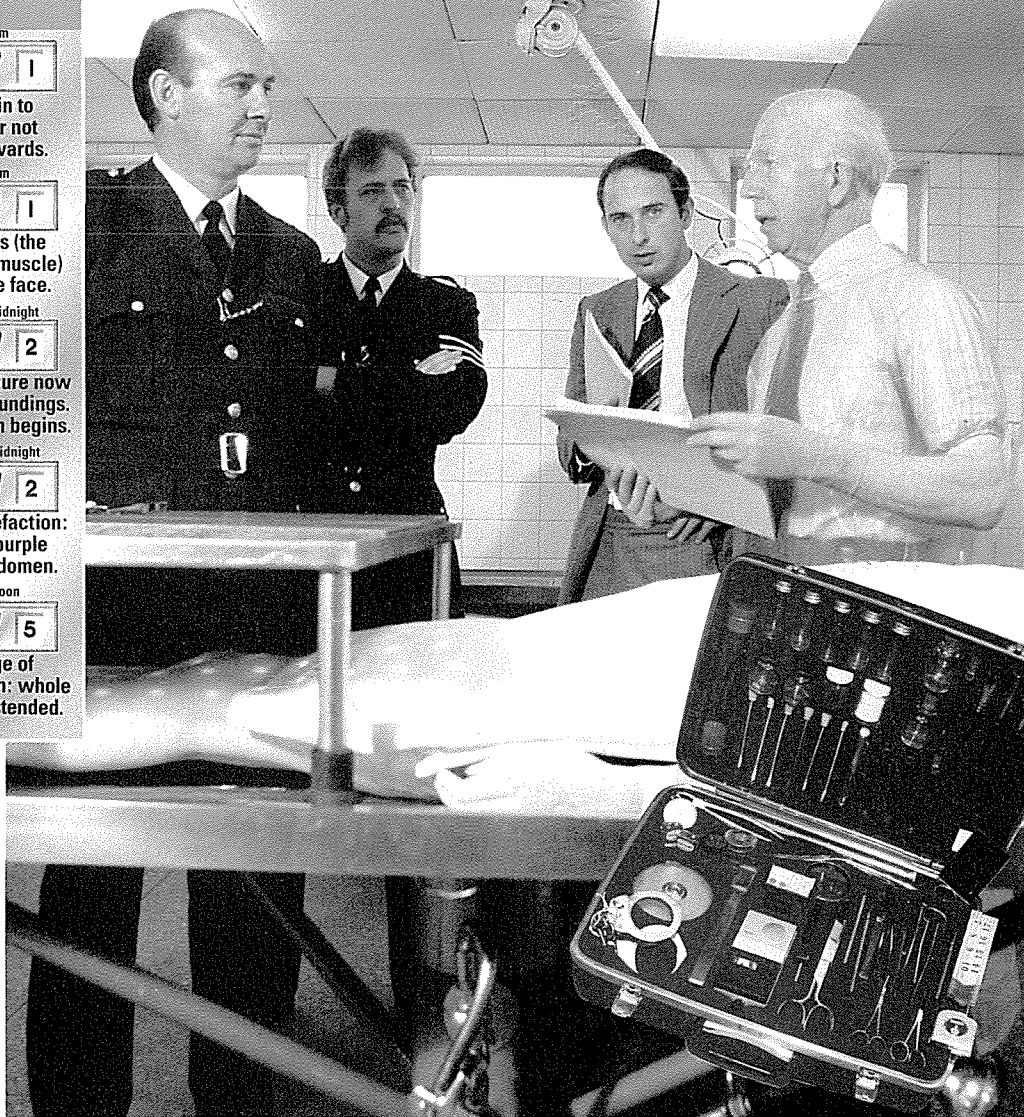
Signs of putrefaction: green and purple stains on abdomen.

Saturday - noon

12:00 5

Later stage of decomposition: whole body now distended.

The pathologist must heed external factors when pinpointing the time of death. A naked body exposed to cold weather loses heat quicker than a clothed one found in a warm house. A corpse submerged in water loses heat twice as fast as one found on dry land. And decomposition occurs quicker in a warm, wet atmosphere.



Inset Aldus Archive

Telegraph Colour Library

the capture of victim's attackers.

After an initial examination, the body is taken to the mortuary, where it is stored at low temperature to preserve any evidence. The police inform the coroner, a government official charged with investi-

gating sudden death, who arranges for a pathologist to hold a post-mortem (Latin for 'after death') examination of the body. Once the victim has been identified by a relative or police officer, the post-mortem can begin.

The pathologist first examines each article of clothing worn by the victim, looking out for any clues to violent death. Cuts or tears in the garments could reveal knife or bullet holes; fibres or hair could give a clue to the assailant; and traces of earth or dust might indicate a struggle or that the body had been dragged some distance.

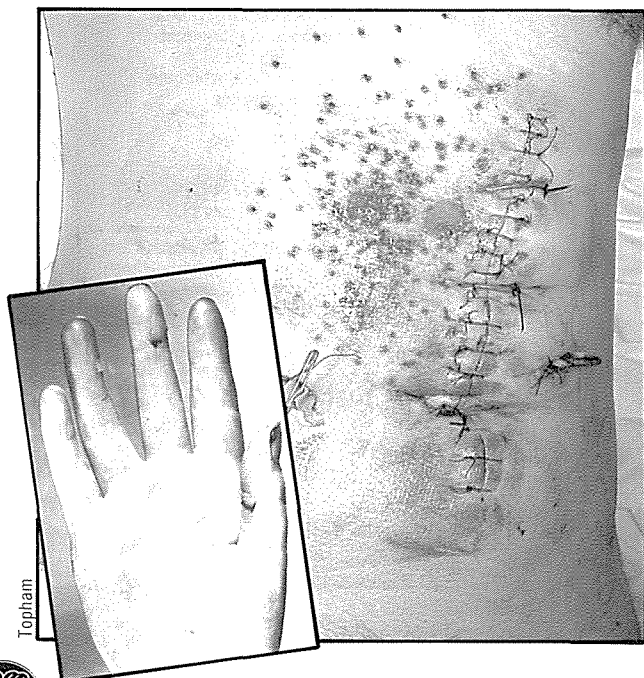
Samples of the victim's own hair are taken, so that it can later be distinguished from any hairs left by the murderer. Other samples taken might include scrapings from beneath the victim's fingernails. All details are noted down by the pathologist and the samples put into polythene bags, labelled, and sent to a forensic science laboratory for analysis. In London, the Metropolitan Police Forensic Science Laboratory carries out over 30,000 investigations each year.

Marks of murder

The pathologist next weighs the body, and then begins a painstaking examination for wounds, bruises or scratches that might reveal the cause of death, or give a clue to the murder weapon or even the killer.

A pathologist can tell from the

Samples of shot are removed from a shotgun wound and sent to the forensic science laboratory for examination. The pathologist then tries to gauge the range and direction of the fatal shot. A rough guide in judging distance is that the spread of pellets in inches equals the range in metres. A circular pattern indicates a discharge at right angles to the body, an elliptical wound indicates the shot came from the side. Knife wounds on the hand (inset) are evidence of an attempt to fend off or grab the murder weapon.



Topham



shape of a knife wound whether a single or double-edged weapon was used. Additional scratches show that the victim could have put up a fight. If there are no scratches, the victim may well have been caught by surprise.

If the pathologist finds gunshot wounds, he will have the body x-rayed. The x-rays should reveal the location of the bullet as well as the path of entry.

On occasions, knife and bullet wounds can look similar, and the pathologist might have to use a scanning electron micrograph – a highly sophisticated microscope – to show up the smear of metal left by the bullet.

He then turns his attention to the inside of the body in his search for clues as to cause of death, taking samples of tissue, blood and other bodily fluids for analysis. These are carefully stored and labelled. In the past, some murder trials have failed because samples from different bodies could have been confused, as happened during the trial of Marie Bresnard, the 'Black Widow of London', in France.

The poison detector

If the pathologist is still unsure exactly how the victim died, he calls in the toxicologist, who specializes in detecting poisons, harmful chemicals and bacteria in the body. The toxicologist has a range of sophisticated techniques at his disposal for the analysis of specimens from the 'path lab'. These include:

- **EMIT (Enzyme Multiplied Immunoassay Technique):** an automated testing device that detects the presence of most kinds of drugs in the bloodstream.
- **Thin Layer Chromatography:** a method of chemical analysis that detects 90 per cent of known poisons. Various chemical compo-

Potential clues

such as hair or blood stains found on a victim or at the scene of a crime (inset below) are examined at the forensic laboratory. Bloodstained areas on a murder weapon can reveal a clear fingerprint of the attacker (inset above).



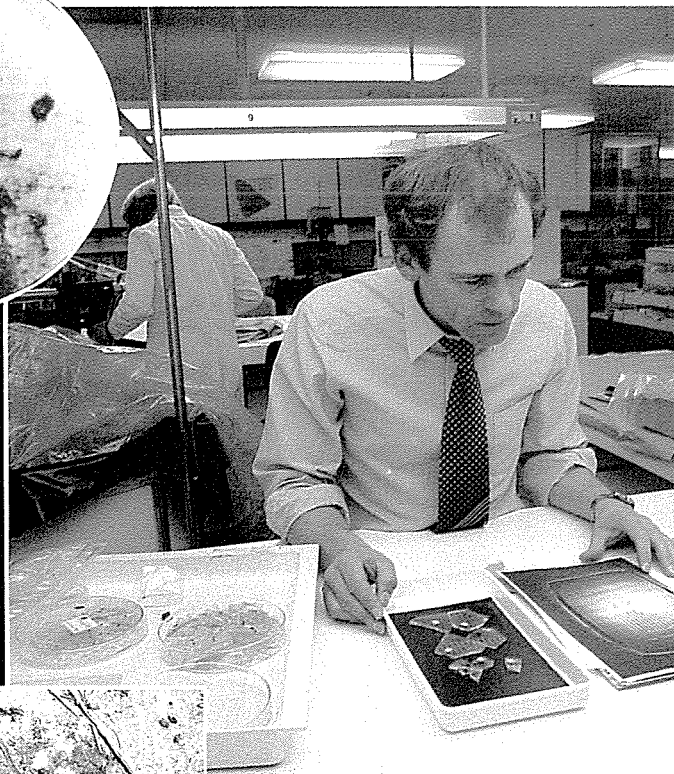
nents show up as different coloured streaks on absorbent paper, reflecting differing chemical structures.

- **Mass Spectrometry:** specimens of blood are vaporized, electrically charged and driven through a magnetic field. The components in the blood samples are deflected by differing amounts by the magnet. These deflections can be recorded on a photographic plate and the chemicals identified from their different spectral patterns. Once the toxicologist has completed his tests, the pathologist puts the body back into storage and writes a report for the coroner on the likely cause of death.

Contact traces

Having discovered how the victim was killed, the pathologist starts to examine the samples he took earlier from the victim's clothes and body, to help find the killer.

When the Yorkshire Ripper murdered his ninth victim, Josephine Whitaker, pathologists found minute quantities of engine oil on her body, probably from her killer's fingernails. The Ripper, Peter Sutcliffe, was a lorry driver. This case illustrates a basic principle of criminology – stated by Frenchman, Edmond Locard in 1910 – every contact leaves a trace. When one person attacks another, something of the attacker will be left on the victim's body or vice versa.



Topham

DEADLY POISONS

Arsenic: Slow acting, tasteless and odourless. Remains in the body after death, particularly the hair. Readily detected by chemical analysis or gas chromatography.

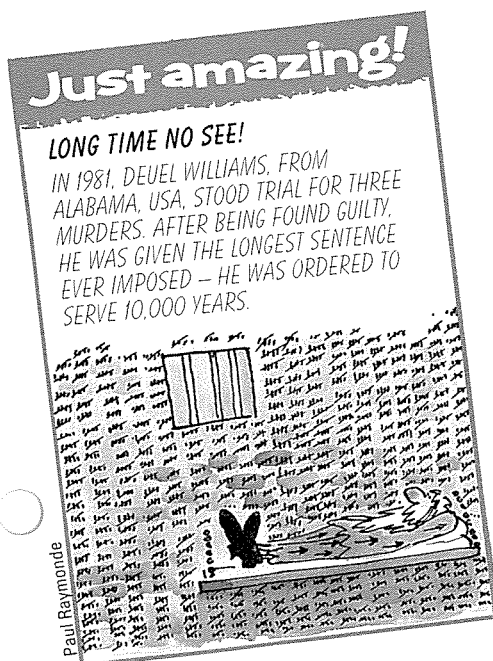
Cyanide: Very fast acting. Can be detected immediately after death by bitter almond smell and pink patches on the skin. Traces persist, particularly in the spleen.

Strychnine: Quick acting, but has sharp bitter taste. Not always detectable.

A single hair recovered from the victim's clothes and examined under a microscope can tell the police much about the assailant. Infallible proof that the hair came from the murderer can be obtained by 'neutron activation analysis' – placing the hair and a sample of hair from the suspect in a nuclear reactor, bombarding them with neutrons and comparing their chemical make-up.

A murderer may also leave tell-tale fibres from his clothing on the victim that are detectable under a microscope. After a full analysis, the scientist can form a clear idea of what the murderer was wearing from just a few fibres. Leslie Stone, the Railways killer, was caught because a thread from his victim's clothes was found on his suit.

Similarly, the smallest glass or paint fragments can be detected on clothing. If hair, fibres, paint or glass fragments link a murderer and his victim, it could send him to jail for life.





VIEW ROGUES GALLERY

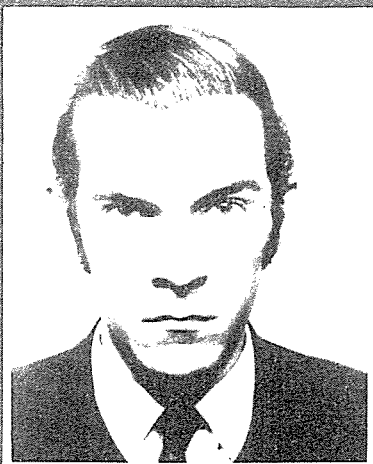
John George Haig, known as the *Vampire Killer*, killed six people and immersed their bodies in a bath of acid. He came unstuck when the dentures of his last victim were found undamaged.

Graham Young, a compulsive poisoner, poisoned his father, sister and a friend in 1962. After his release, he went on to kill another two people ten years later. Over 70 workmates became victims of his poison obsession.



Topham

Peter William Sutcliffe terrorized the women of Yorkshire for a period of five years, between July 1975 and November 1980. In that time, he murdered a total of 13 women and attempted to murder another seven. He was caught by a sharp-eyed PC who checked out his car number plates and found them to be false. He was sentenced to 30 years minimum.



Topham

Dennis Andrew Nilsen was found guilty of six murders and two attempted murders at his trial in 1983. After human flesh was discovered in the drains of the house where he lived, he confessed to a total of 15 murders. All were young men whom he had befriended and invited home with him. Only one of his victims was ever reported missing.



Topham



Associated Press



Topham

John Reginald Christie confessed to six murders at his trial in 1953. He was also thought to have killed a further two victims - Beryl Evans and her daughter Geraldine. Christie's crimes came to light after he moved home and the next tenant discovered some bodies in a hidden cupboard. A police search revealed even more bodies.

Associated Press



Theodore Bundy received three death sentences at different trials. He was convicted when bite marks on one of his victims matched his teeth.

Wayne Williams, found guilty of two murders, but may have committed 28. Found near the scene of his last murder, fibres in his car matched the victim's clothing.



TERRORISTS



SPECIAL UNITS



HOSTAGES

Gamma/Frank Spooner Pictures



DAWN ON 5 APRIL 1988, AND for the 97 passengers and 15 crew aboard Kuwait Airways flight 422, a nightmare has just come true. A scheduled flight from Bangkok to Kuwait has been hijacked by a gang of Islamic terrorists.

In such a situation, negotiations are always the first option for the authorities. Storming the plane — although highly publicized — is the last resort to end a confrontation.

As soon as a hijack takes place, a huge international machine swings into action. Criminologists, psychologists, army commanders, police officers and academics all assess each area of the situation and try to come up with a plan by which, ideally, all the hostages would be released unharmed, and all the hijackers would be disarmed and taken into custody.



A waiting game

Highly sophisticated techniques of psychological assessment are now used when a hijack is in progress. The most important weapon of the counter-terrorist official is not a submachine gun or a stun grenade, but time. As the minutes turn into hours, and the hours into days, a fresh, fit terrorist becomes dirty, tense and tired — demands turn into requests, deals turn into trade-offs, hostages become companions.

While the authorities can work in shifts, the hijackers have to remain alert 24 hours a day — ready, if necessary, to start shooting. A week of this constant pressure can



The Kuwait Airways hijack ended in Algiers, when the terrorists fled without warning. Balaclava'd gunmen seized control of the cockpit during the hijack of a TWA jet in Beirut in 1985 (inset).

weaken the resolve of the most hardened fanatic.

However, the longer a hijack continues, the greater the problems become. When a hijack is in progress, temperatures inside a stationary aircraft, particularly in the Middle East, can rise to a humid 45°C. This debilitating heat, combined with the constant fear of death, and the huge quantities of adrenalin produced by the body, can cause severe illnesses.

Hyper-tension often results, putting great stress on the heart. Acute claustrophobia, fatigue and insomnia are all common side-effects. Freed hostages can suffer from psychological problems for months after their ordeal. An extra complication arises when a hostage begins to sympathize with the terrorists — a condition known as the Stockholm Syndrome.



Bargaining ploys

The counter-terrorist authorities can use time to their benefit by slowly chipping away at the terrorists' main demand — the release of prisoners, payment of a large ransom, and so on. They make contact by radio, and give the hijackers every-

thing they want to survive, such as food, water and medicines. By treating them well, they hope that the hijackers will slowly wear down and feel less desire to challenge authority and make difficult demands. If they refuse to compromise, however, the officials might cut

Just amazing!

HIJACK HOWLER

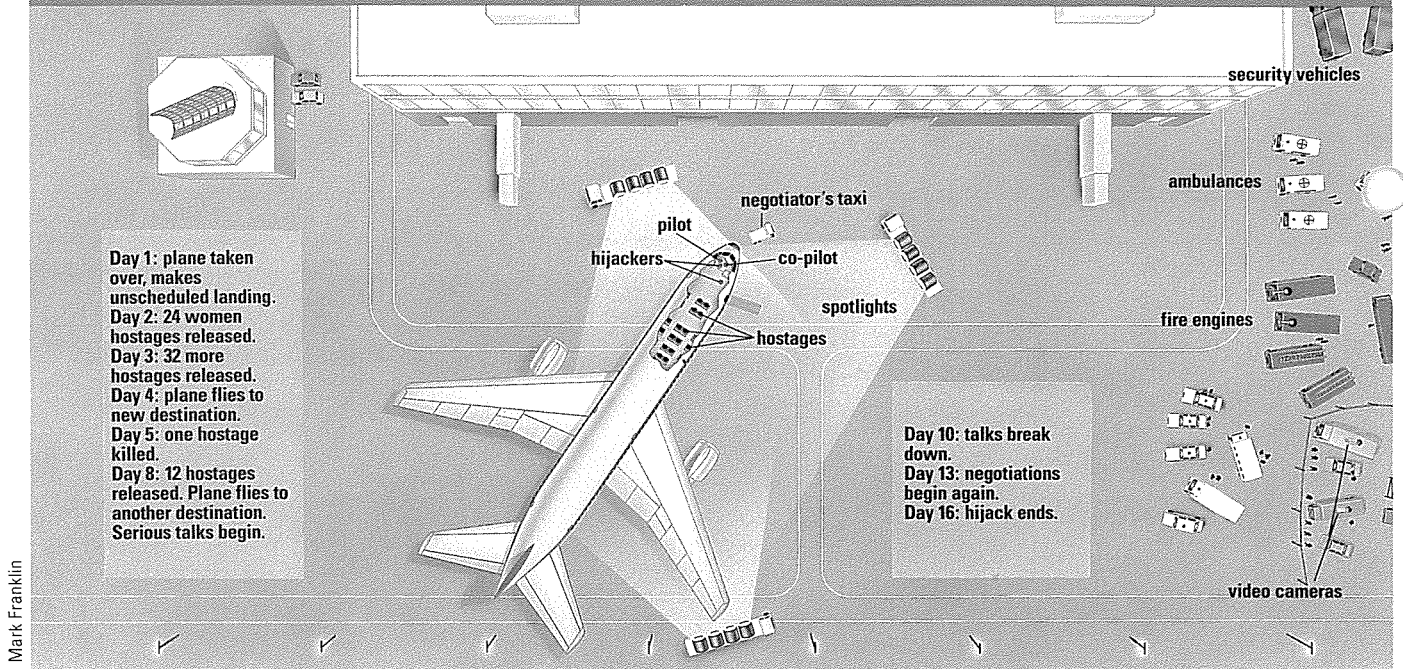
ON A FLIGHT ACROSS THE USA IN 1976, A PASSENGER SUDDENLY STOOD UP, POINTED A GUN AT A STEWARDESS AND DEMANDED TO BE FLOWN TO DETROIT. WHEN SHE TOLD HIM THEY WERE GOING TO DETROIT ANYWAY, ALL HE COULD DO WAS SIT DOWN AGAIN.



Paul Raymond



TIMETABLE FOR A HIJACK



off their food and water supplies. So, the longer a hijack continues, the less control the terrorists have over their own fate.

But there are also problems with extended negotiations. Lengthy delays in meeting hijackers' demands can lead to violence – as occurred in the Kuwait Airways hijack, when two passengers were killed.

Special forces

The major concern of all the officials on the ground, though, is the safety of the hostages. This is why armed intervention is avoided whenever possible – the risk of hitting a passenger is too high. Most countries do, however, have their own counter-terrorist force on standby in case of a hijack. In Britain, this unit is called the Special Air Service, or SAS.

STOCKHOLM SYNDROME

When a TWA jet was hijacked to Beirut in 1985, many of the hostages began to show signs of a condition known as the Stockholm Syndrome. Named after a bank hold-up in Sweden, the Syndrome results in close emotional bonds being formed between hostage and captor.

In the TWA hijack, for instance, the pilot, John Testrake, defended the gunmen, saying they had a 'just grievance'. This kind of attachment by victims to terrorists when under extreme stress and in mortal danger is well recognized by psychologists. But it adds a dangerous new facet to the negotiations.

If the hijacker forms a close relationship with a hostage, the hostage stops being a bargaining tool and becomes a human being – and more difficult to shoot. Should a chance to escape appear, the hostage may also think twice, about putting himself, and his rescuers, in danger.



A civilian hostage escapes from the burning Iranian Embassy in London, moments after the SAS stormed the building. Out of sight, a marksman from Scotland Yard's crack C11 unit keeps him covered

The SAS operate as an extension of the police resources, but they are, in fact, a regiment in the British Army. When they are called to a hijack, they design intricate plans for successful stormings of the plane, should it be necessary. They have maps of the airport buildings, plans of the aircraft itself, and detailed dossiers on the terrorists themselves. If any hostages are released by the hijackers, they are closely questioned about the behaviour of the terrorists, and their moods and feelings.

The SAS had their most violent brush with terrorists when they relieved the siege of the Iranian Embassy in London, by Arab separatists, in May 1980. But the SAS

has such a high reputation for efficiency and smoothness of operation, that they are often called out to attend hijacks in various parts of the world. One of their biggest operations was in 1977, when, with the help of the German equivalent of the SAS – a unit called GSG9 – they successfully stormed a plane hijacked to Somalia, and freed all 79 hostages unharmed.

Undercover unit

There is a second British counter-terrorist force called SO10, attached to Scotland Yard. This unit was called to the Kuwait Airways hijack to give information and advice on undercover surveillance techniques.

One of the techniques this unit might recommend is flooding the aircraft with invisible infra-red light. By using special cameras that respond to infra-red, they could then see exactly what was happening in the plane, day or night. Inside, the hijackers would be completely unaware of what was going on.

Q THE GERM SPREADERS

Q TOWN RATS

Q INSECTS

URBAN PARASITES

Kim Taylor/Bruce Coleman

IN EVERY CITY, THERE ARE millions of creatures – most of which lurk in walls, sewers or under floorboards. Some, such as houseflies, we see every day, others, such as rats, are silent hunters of the night.

The common housefly is potentially the most dangerous insect in the world. It can transmit 30 diseases and parasitic worms via vomit drops – partially digested food and saliva which is regurgitated on to its next meal to prepare it for eating.

The housefly rarely strays more than a kilometre from its place of birth. Most of its life will be spent moving between food and filth. It breeds on rotting organic matter, including excrement on which it will also feed before flying off to find a bowl of sugar on which to land. The common housefly has a sense of taste that is ten million times

more sensitive than that of a human being.

There are approximately 3,500 species of cockroach and the vast majority are tropical. In the last 200 years, they have been introduced to the cooler European climate where most are dependent on heated buildings to survive. Cockroaches are nocturnal creatures. At night, they crawl out of their warm homes

– often inside the television set – to scavenge for food. By morning, they disappear without trace.

Each year, a hundred people in England and Wales catch Weil's disease. The symptoms are fever, jaundice, a swollen liver and internal bleeding, leading eventually to a slow painful death. The virus is carried in rat's urine and is transmitted to Man through cuts and grazes

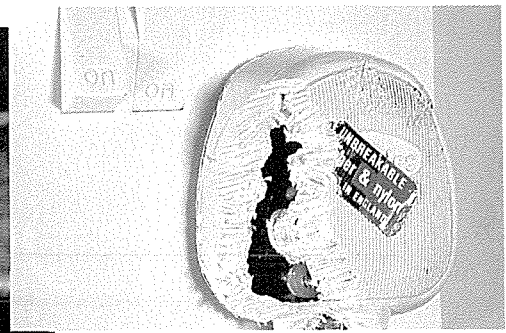


Papilio

Bluebottles prefer to lay their eggs on dead flesh. When the eggs hatch, the maggots burrow into the meat. The body of a rat can feed about 4,000 maggots before they emerge as flies.

Cockroaches eat a wide range of food including dead animals and kitchen waste. They destroy foodstuffs, partly by gnawing them, but also by fouling them with their unpleasant smell.





Rentokil

The curved incisor teeth of rats require continual wearing down by gnawing anything which is hard wearing. For this reason, water pipes and electrical wiring are frequently attacked by rats, causing flood and fire hazards.

Rats are scavengers – they will eat almost anything they can find. They have been known to steal live ducklings from city parks and several elephants in Hamburg zoo have had parts of their feet eaten by rats.

in the skin. Contact with contaminated water from canals or sewers is the usual means by which the disease is spread.

Rat's highway

The 17,000 km of sewer under London make an excellent home for the brown or sewer rat. Each kilometre can support about 500 rats, and the warm humid conditions are perfect breeding grounds. A pair of rats and their offspring produce about 1000 babies a year.

Another rodent which is found wherever Man has set up home is the house mouse. Mice live inside buildings, often in walls. From here, they will gnaw their way into the kitchen. They shed 80 droppings every day and urinate constantly to mark their territory.

Richard Vaughan/Ardea

In the nineteenth century, sparrows were introduced to New York from Britain to keep the number of insects down. Now, they are common inhabitants of all US cities and are considered pests – they are often referred to as 'flying mice'.

Another European bird which was introduced to America is the starling. These birds flock to cities at night to take advantage of the higher temperatures usually found in cities. Each flock can number up to half a million birds.

City wildlife

Pigeons have adapted well to urban life. They will rummage for food among rubbish tips and dustbins. They can carry and spread a number of diseases and fleas. Bird fanciers lung can be caught by inhaling dry pigeon droppings.

As cities grow in size and number, increasingly more animals make their homes in them. Even



birds of prey, such as kestrels and peregrine falcons, are attracted to cities with their rich food supply – plenty of small birds and rodents.

THE DISEASE CARRIERS

PEST RODENTS

rats

DISEASES CARRIED

Weil's disease, rabies, bubonic plague, typhus, salmonella

BIRDS

pigeons, starlings, sparrows

Typhus, spotted fever, salmonella

Typhus, tapeworm, ornithosis, salmonella, encephalitis, histoplasmosis

INSECTS

cockroaches

Salmonella, threadworm, dysentery, jaundice, gastroenteritis, boils, pneumonia

houseflies, bluebottles

Dysentery, anthrax, cholera, gangrene, salmonella, tapeworm, boils and abscesses, threadworm



Millions of starlings migrate to British cities from Central Europe every winter. They are messy birds – a starling can shed half its own body weight in droppings every day.





Ardea

ANIMAL KINGDOMS

Animals form families readily - even if temporarily. A new male lion in a pride will kill cubs not fathered by him to make way for his own offspring.

Zebras band together in their hundreds. Their stripes set up a dazzling pattern, which makes individual animals hard to distinguish and hence less vulnerable to predators.

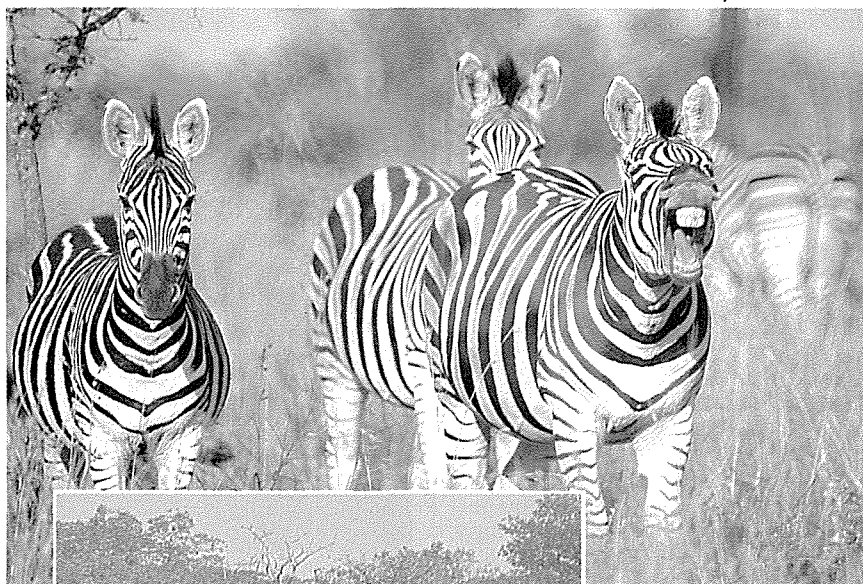
ALONE, AN ARMY ANT WILL quickly die. But as part of an enormous swarm it is one of the most successful - and deadly - creatures in the world. Nothing can survive in the path of army ants when they are raiding for food.

Other types of animal, too, habitually live in groups for one reason or another. Both wolves and hyenas, for instance, hunt in packs. As a group they can bring down a beast much too big and strong for any individual to tackle. And their prey, such as zebra and wildebeest, also move together in large herds to make themselves less vulnerable to attack.

Sometimes, a normally solitary animal will join others of its kind for a special event like mating. In other cases, two creatures of quite different species will live permanently together, each benefitting from their close relationship.

Farmer ants

Ants may be helpless by themselves, but in colonies of thousands or even millions, they are capable of the most astonishing feats.



Bruce Coleman Ltd



Gerald Cubitt/Bruce Coleman Ltd

Elephants roam in herds, but the sexes stay separated. Female elephants form strong bonds in groups headed by matriarchs, while bull elephants tend to form looser connections.





J. Allan Cash Ltd.

Black garden ants live in colonies populated by males and workers, and dominated by a queen. Each has a specific role. In summer, the males mate with virgin queens from other colonies, while the workers scurry around (1). The male dies after fertilizing the queen, who then breaks off her wings (2) and starts a new nest. There, she lays the eggs, which are carried by the workers to a warm place (3). Workers also bring food. They tickle aphids to make them excrete honeydew (4).

Mark Iley



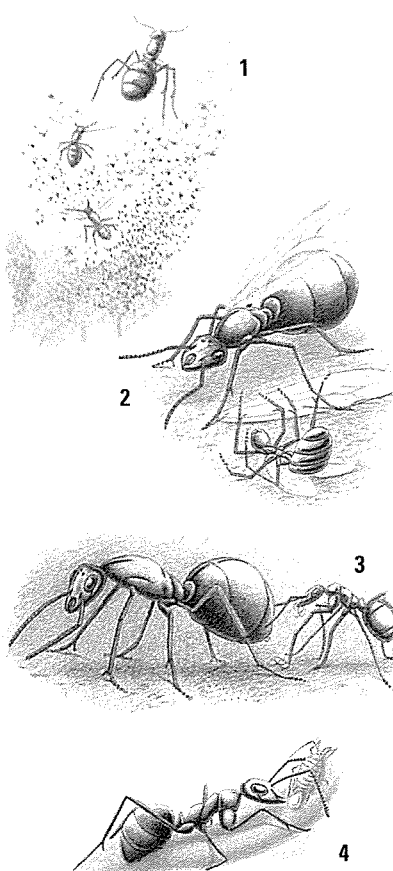
Queen



Male



Worker



Like miniature farmers, some ants tend herds of aphids (such as greenfly), letting them graze on plant sap during the day and returning them to be 'milked' in the nest at night. When stroked by their keepers, the aphids give off drops of a sugary liquid made from the plant sap which the ants then drink.

Another kind of ant, the leaf-cutter, farms in a different way. The workers slice off pieces of leaves with their sharp jaws and then carry these back to their underground homes. There they chew the leaves until soft, spread them out and use them as fertilizer to grow a unique type of fungus that is the colony's staple diet.

Ant raiders

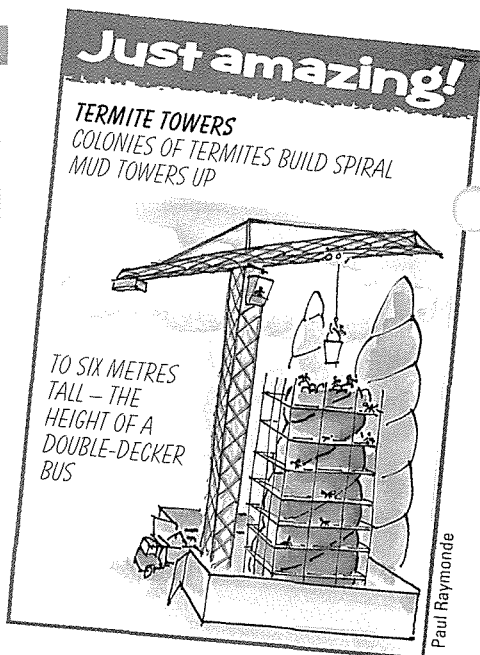
The so-called Amazon ants invade the nests of other ants, spraying a chemical into the faces of any defenders to confuse them. Then the Amazons kidnap the eggs and larvae in the nest and take them back to their own home. When the stolen young mature, they become the Amazons' slaves, digging, building, and even helping to carry out future raids for their captors.

No ant society, though, is as extraordinary as that of the army ants of South America. Instead of constructing an ordinary nest, a colony of army ants joins up to make a living 'bivouac' in a hollow

tree or other sheltered place. The millions of ants in the swarm hook their legs together to form a seething mass, with the queen and her young protected deep inside. During periodic raids, huge numbers of army ants march across the forest floor like a brown river, overwhelming everything in their path.

Hunters and hunted

In packs with up to two or three dozen members, wolves can successfully ambush animals as big as

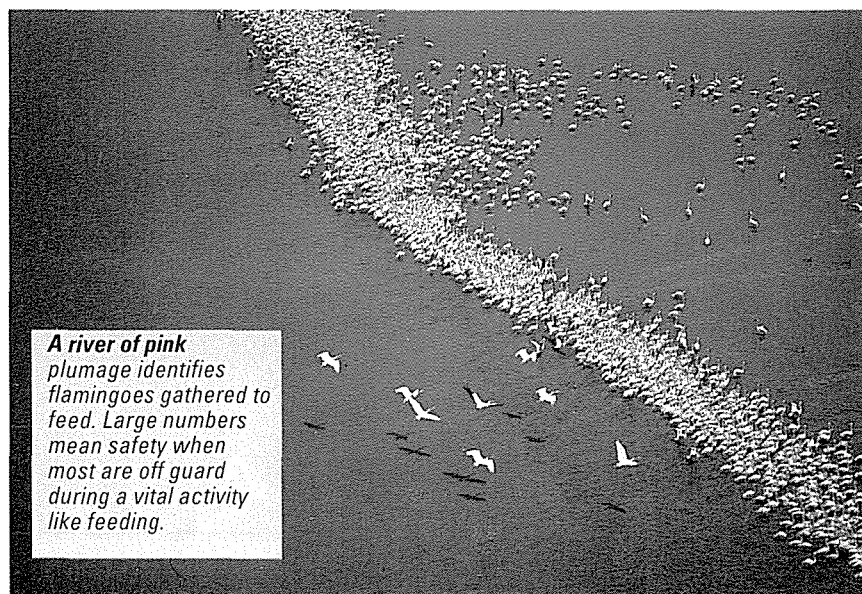


Paul Raymonde

a moose or an elk, harrassing and tiring their victim before finally dragging it down. On the plains of Africa, roving bands of hyenas and hunting dogs work in a similar way. Having first separated an animal from its herd, they jump on it and, by sheer weight of numbers, bring it to the ground. Then the rest of the pack - the young and their mothers - join the hunters to devour the kill.

To afford some protection against such strikes, the hunted animals themselves live and graze together in large groups. Zebra, antelope, wildebeest and other targets for the hunters of the plains wander about in herds numbering many thousands. For the same reason, fish often swim in shoals, confusing an attacker, such as a shark, by swimming together in a zig-zag path.

Sometimes, though, the strategy of certain fish to remain in shoals can backfire. Groups of pelicans sometimes form a line across the water, beating the surface with



A river of pink
plumage identifies
flamingoes gathered to
feed. Large numbers
mean safety when
most are off guard
during a vital activity
like feeding.

Bruce Coleman Ltd



their wings to drive shoals of small fish into shallower water where they can be easily scooped up. Meanwhile, danger beneath the waves comes from the toothed whales which, attracted by great gatherings of fish, band together in schools themselves to improve their chances of a sizeable catch.

One for all, all for one

It can be very hard to tell with some creatures where an individual ends and a colony begins. Corals, for instance, are made up of enormous colonies of tiny animals called polyps. As a polyp grows, it forms a hard, chalky cup around itself and feeds by trapping even smaller creatures in its tentacles. Eventually, a lump sprouts from its side and develops into a new polyp. In time, this 'daughter' polyp also gives rise to its own offspring, and so the process repeats itself over and over again, until a vast city of corals is built up forming a tropical reef.

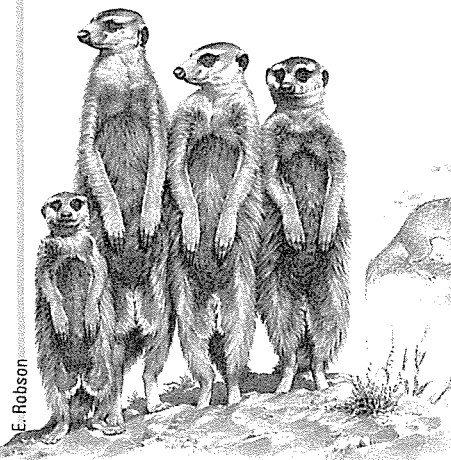
Strange as it may seem, the deadly Portuguese man-o'-war, with its long stinging tentacles, also consists of a polyp colony. The big gas-filled float of this jellyfish is really a single polyp that has become highly specialized. Three other polyps hang in a tangled mass below the surface. Three kinds of polyp are concerned with catching prey, feeding and reproduction.

The most advanced of animal societies are those in which all members of a group care and work for one another. Elephants have an especially strong communal spirit, so that if one elephant is hurt, the others in the group will go to its aid and try to help it recover. They may bring leaves, berries and branches until it is well again.

Like human children, young elephants learn by spending years with their mother and with the rest of the herd. An old female — the

A UNITED FRONT

Few animals live in such a closely-knit community as the amazing meerkats of the Kalahari desert in Africa. Relatives of the mongoose, meerkats spend much of their day digging deep in the sand for grubs and lizards. But while a meerkat's head is in the ground, its rear end is vulnerable. By living in groups, these curious looking animals can take turns to, literally, stand guard for others. Since they live in burrows, meerkats like to bask in the sun to warm up, and as they need to hunt as well as fend off hunters who prey on them, meerkats have evolved a society that allows some members to forage for food while others keep guard. Meerkat females will even 'babysit' a mother's young while she goes out to forage. Everyone, though, has to take a turn at sentry duty. When one is exhausted after about an hour's watching, another immediately comes up to trade places.



E. Robison

matriarch — is always the herd's leader, having acquired the most knowledge of trails and the whereabouts of food and water.

Even more advanced is the social

African hunting dogs are very social creatures, hunting in packs of up to 60 or more. Their sense of smell and hearing is highly developed and they usually target antelopes or even larger game for their prey. Such is the intricate organization and hierarchy within the group that it is possible a lone dog would not be able to survive on its own.



Richard Packwood/Oxford Scientific Films

life of monkeys and apes. Although some monkeys do live in small family units, most dwell in larger groups led by several adult males.

During the first few weeks of their life, baby baboons are black and, hence, very noticeable. Attracted to the new animals, other members of the troop continually try to touch and caress them so that the infants quickly learn to recognize all of their neighbours.

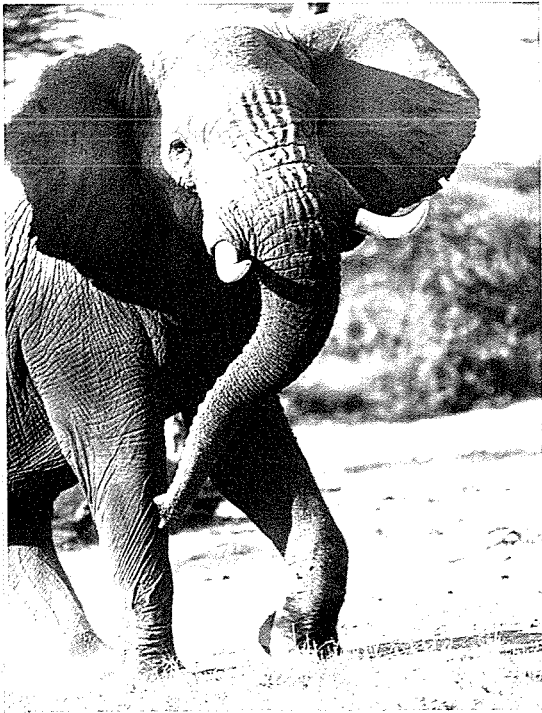
Clever chimps

Because it is perhaps the cleverest and most adaptable of apes, the chimpanzee has an exceptionally rich social life. Young chimps must spend ten years or more watching, playing and learning from their fellows before they can properly fend for themselves.

Like people, chimps have a variety of sounds and facial gestures by which they can communicate with one another. They use natural weapons and tools to defend themselves and to poke tasty termites out of their mounds. The young chimps must learn all these skills within the safety of their group.

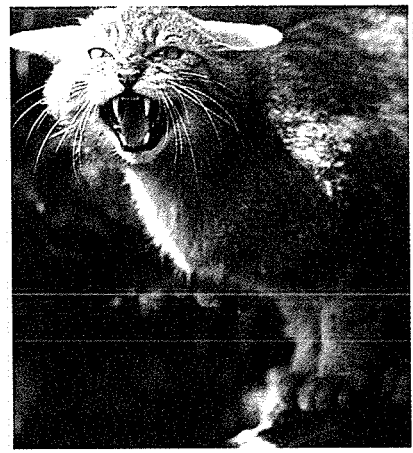


LEADER OF THE PACK



Peter Davey/Bruce Coleman Ltd

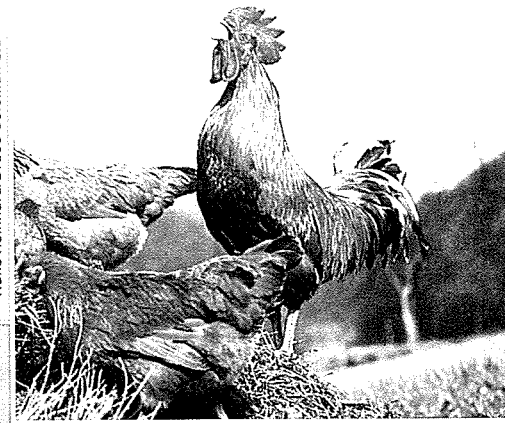
The wild cat. Almost from birth the male works out strict boundaries across which other cats step at their peril. If an aggressor does successfully penetrate rival territory without attack, the boundary lines are redefined.



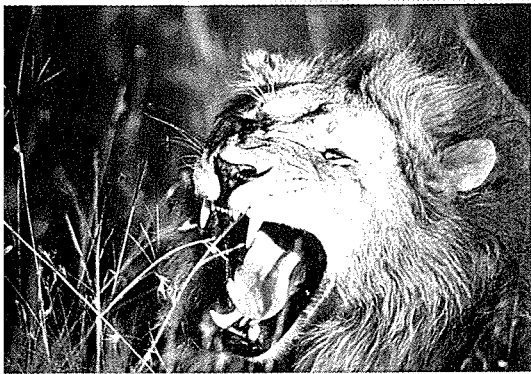
Hans Reinhard/Bruce Coleman Ltd

A bull elephant, although large in stature, exists in a matriarchal society, with the oldest female taking the role as leader of the pack. The social bond between cow elephants is exceptionally strong, but between the young bulls there seems to be little co-operative behaviour.

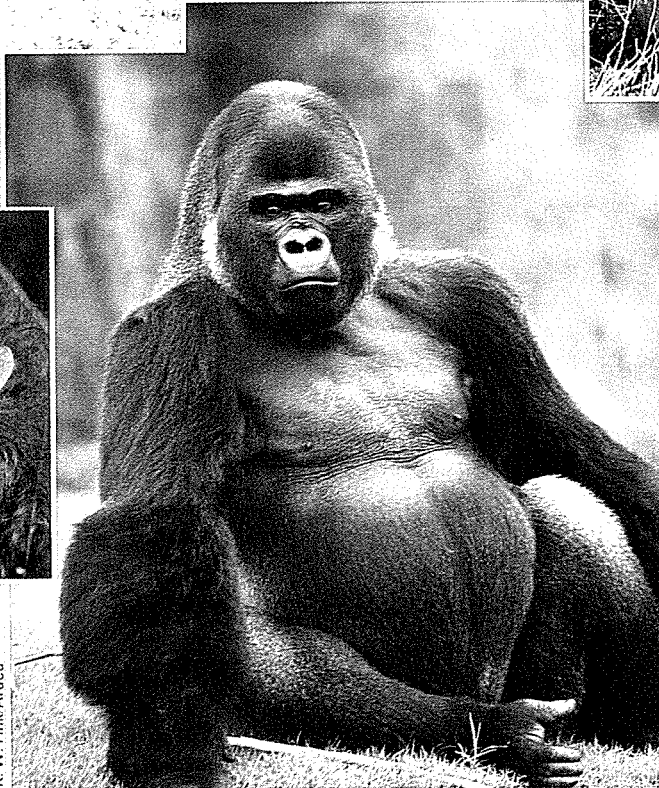
Hans Reinhard/Bruce Coleman Ltd



The male lion rarely hunts, although the males eat first. Most prides contain two males, who protect the pride's territory.



A rooster crows to show that he is confident about his position at the top in the pecking order. Birds establish a hierarchy to determine individual roles within groups, which helps to maintain an orderly continuation of the species.



Moose lock antlers to determine a dominant male. The winner will gain access to the harem of females, which will ensure a continuation for his line. Antlers are almost exclusively sported by the males.

Ardea

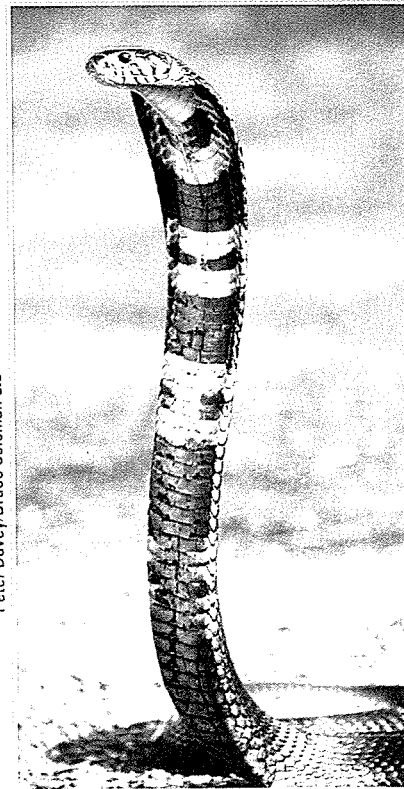
K. W. Fink/Ardea



Steven C. Kaufman/Bruce Coleman Ltd

The silver-back male gorilla is twice the size of the five females in his harem. It is the bond between him and his 'wives' that keeps the group together.

Peter Davey/Bruce Coleman Ltd



The king cobra. Less deadly than the female, the male is more impressive. Raising its magnificent hood, it hypnotizes its victim before striking.



MAN THE HUNTER MAN THE FARMER

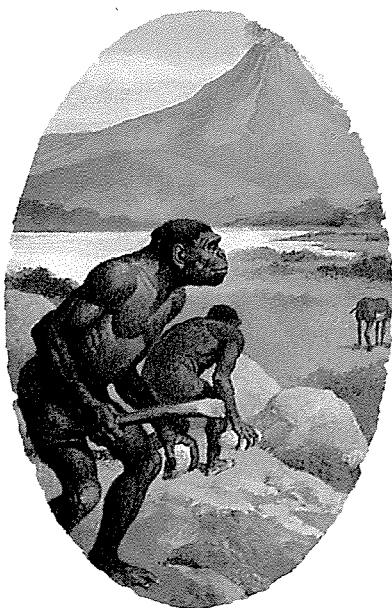
MAN THE EMPIRE BUILDER



Zefa

Still from *Gorillas in the Mist*. Warner Bros

Family life is important for humans and gorillas alike. As primates they share a common heritage, and both are highly social animals who prefer to band together in groups.



Australopithecus lived about three to four million years ago in Africa. He stood just over one metre high, had a rolling gait, large jaws and teeth, and a brain, about 500cc, no larger than that of an ape.

THE EVOLUTION OF MAN

OF ALL THE ANIMALS IN THE modern world, humans alone change the environment to suit themselves rather than adapting to their environment. Yet early human history is one of adaptation, and one of the most decisive events in Man's evolution was the development of bipedalism – walking upright on two feet.

The footprints of a small group of Man's early cousins, found in a layer of dried volcanic mud in Tanzania, Africa, 3.75 million years old were made by two adults and a child. Named *Australopithecus*, their brains were no bigger than those of apes, but there is a possibility that they used very simple tools, such as sticks and naturally-shaped river pebbles.

Man's ancestors were primates, able to hold things between fingers and thumb, with two mammary glands on the chest, eyes in the front of the head, and a covering of

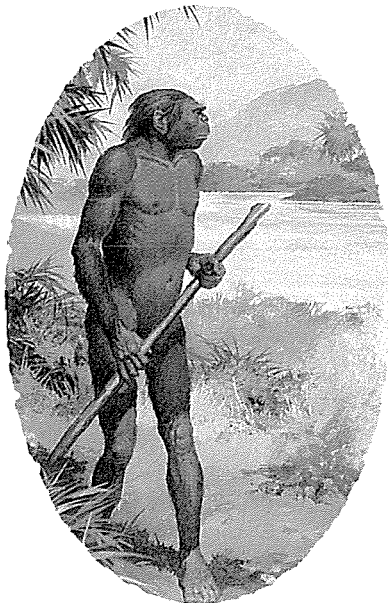
hair. They lived in the thick forests of Africa. Between 10 and 7 million years ago, a climatic change caused the thinning of these forests, and the emergence of wide grasslands and shrublands.

Evolutionary split

Some of the primates who had lived in the trees – using their hands with their opposed thumbs to swing from branch to branch – now began to emerge from the shrinking forests, possibly due to the pressure of competition for food. Those primates that would evolve into the African apes, the chimpanzees and gorillas, stayed among the trees, developing their knuckle-walking gait, and dividing their time between trees and the ground. Others, evolving into grassland dwellers, developed the upright stance and two-legged walk that characterizes humans.

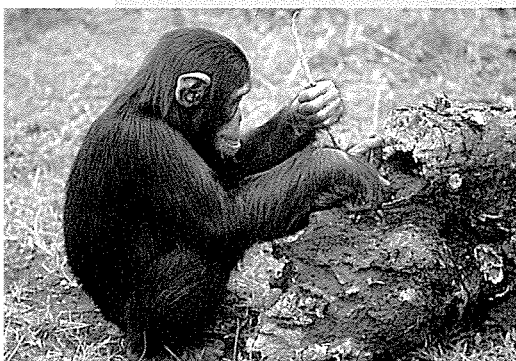
Out in the open, they lived mainly on shoots and fruits, and covered



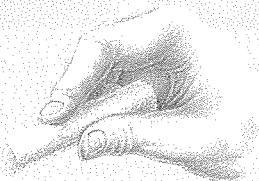


Homo erectus lived over one million years ago. The heavy-browed creatures cooked their food on fires which helped them to survive the cold.

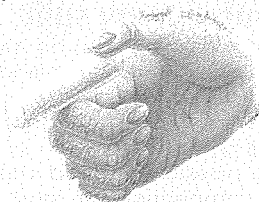
PRECISION GRIP



Human



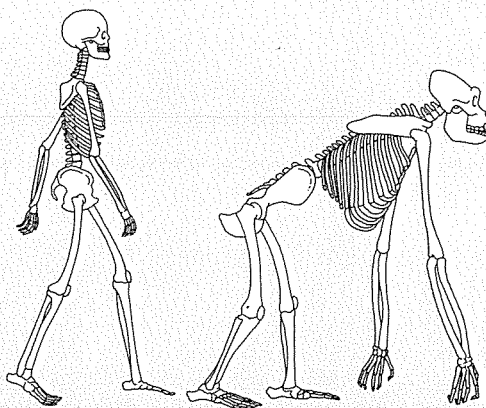
Chimpanzee



The chimpanzee can use simple hand tools, but the shape of his hand limits his skill. His hand closely resembles that of a human, but the absence of a fully opposable thumb means that the chimpanzee has no precision grip. Although his fingertips act as delicate instruments of touch, his inability to grip means he cannot use tools with accuracy.

SKELETAL DEVELOPMENT

The skeletons of Man and gorilla are adapted to their differing style of motion. The long pelvis of the gorilla accommodates the muscles necessary for travelling on all fours, and his fingers are curved inward for knuckle walking. Man, with his striding gait, has a much shorter pelvis, and his skull is balanced on top of the spinal column, unlike that of the gorilla which is held forward. The gorilla also has strongly developed big toes which he uses to grasp branches.



long distances, stripping bushes and trees as they moved. They ate very little meat, but may have supplemented their diet by scavenging what predators had left, or picking off the occasional sick or very young animal from a grazing herd.

Natural air conditioning

One strong possibility is that walking upright served the very practical purpose of keeping them cool. The move from dark forest shade to sun-blasted open country must have caused severe problems for creatures without an advanced cooling system. By standing upright, their bodies absorb 60 per cent less heat than creatures who walk on all fours and expose a far greater body area to direct sunlight.

As the evolutionary line that included the Australopithecines died out, another line was already in progress. Coming from the same origins, but with a larger brain half the size of modern Man's — *Homo habilis* (handy man) probably emerged as a separate species sometime over two million years ago. He was a toolmaker, with developed manual skills for hold-

ing, flaking and shaping tools from rocks and pebbles. Like their predecessors, *Homo habilis* originated in Africa, well before Man migrated into Europe and Asia.

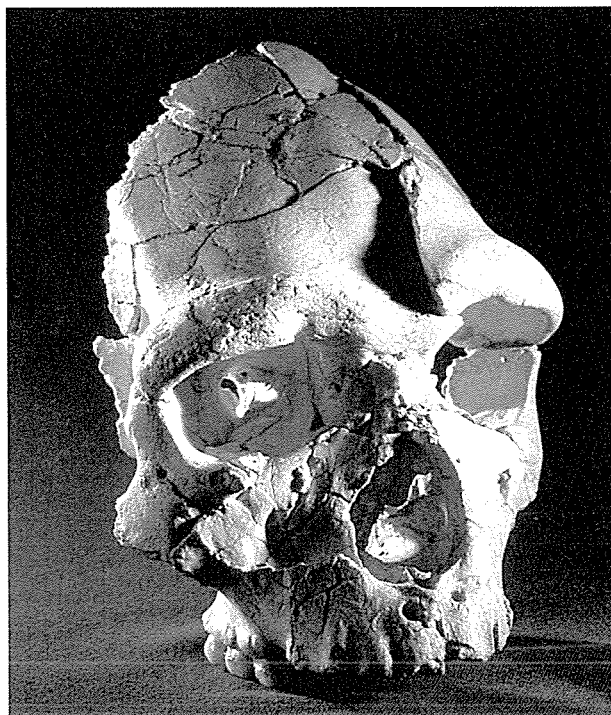
The hunter

With stone-tool technology came the ability to kill and cut up large animals, and Man started to include more meat in his diet.

The larger brain of *Homo habilis* included a significant enlargement of the brain region known as Broca's area, which is associated with language. He was a socially organized creature, arranging, for example, collective hunting trips. The females and children were possibly left at a home base while the men went out.

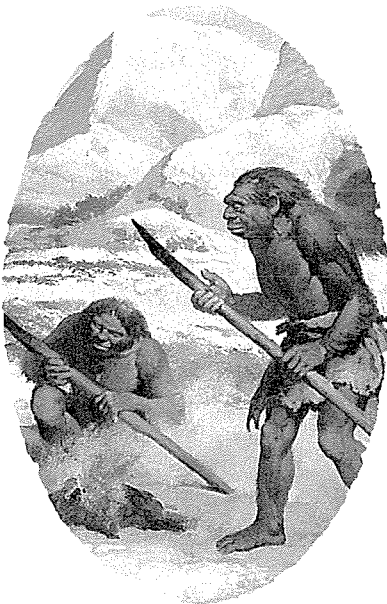
Each increase in brain size is reflected in a faster adaptation to changing conditions, and a widening of skills. The fossil record from 1.6 million years ago shows evidence of a more advanced species, known as *Homo erectus* (upright man). He had a brain capacity of 1,000cc, compared to *Homo habilis*'s 800cc, and modern Man's 1,400cc. *Homo erectus* was a more

Tautavel man, whose broken skull was found near Perpignan in southern France, was an example of *Homo erectus*. This group were proficient hunters with strong nerves and quick reflexes. Their ability to feed, clothe and keep themselves warm ensured continued evolution of the human race.



M. Oster Collection / Musee De L'Homme





Neanderthal man existed about 100,000 years ago. Although primitive in appearance, his hunting techniques showed there was a great deal of communication within the group.

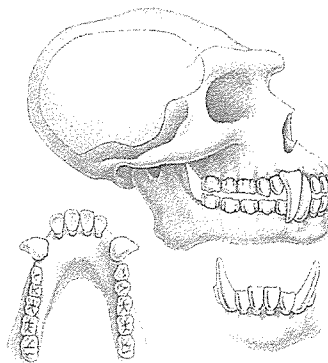
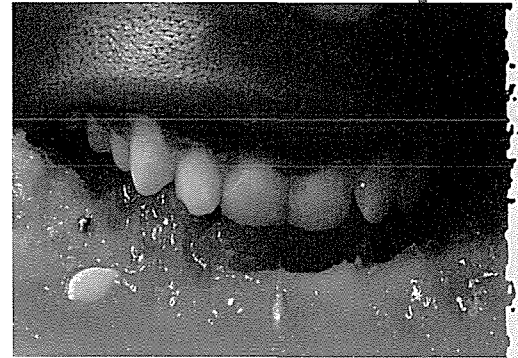
sophisticated tool-maker, and a proficient hunter. He was also the first fire-user.

It was *Homo erectus* who took the human species out into the wider world, out of the African cradle, and into Asia and Europe. His remains have been discovered in North Africa, Greece, Hungary, France, Germany and England in the West, and Indonesia and China in the East. Remains range in age from 1,000,000 to 200,000 years old, although the younger remains have some indications of the next shift, to *Homo sapiens* (wise man).

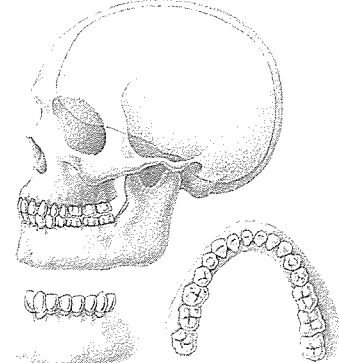
Neanderthal man – *Homo sapiens neanderthalensis* – was established across Europe, the Near East and Central Asia 100,000 years ago, and died out quite abruptly 35,000 years ago. He had a large brain, and a very stocky, muscular body. His teeth

JAW SHAPES

The jaws of Man and ape show marked differences. Man's teeth form a rounded arcade, while in apes they form a rectangular shape. Apes also lack the characteristic human chin. In Man, the gradual shortening at the snout has been accompanied by a reduction in the size of the teeth, especially the canines. Formation and shape of the teeth also differ. Both sets of teeth are adapted to their respective diets. Man's teeth are suited to the slicing action needed to cut through meat or fruit, while the vegetarian ape's teeth are used mainly to grind and chew.



Chimpanzee



Human

Jan De Wit/Zefa

and nose thrust forward, his brow sloped back, his brow ridges were prominent, and his teeth were big.

Despite his appearance, he was highly intelligent, a very skilled tool-maker, and made clothes. He was a thinker, with developed ideas about life and death, who performed ritual burials for the dead.

Moving forward

The most recent stage in Man's development, *Homo sapiens sapiens*, may have descended in part from some advanced Neanderthals, or may have stemmed from a completely separate *Homo sapiens* line from outside the main Neanderthal area of operation. Most likely, there

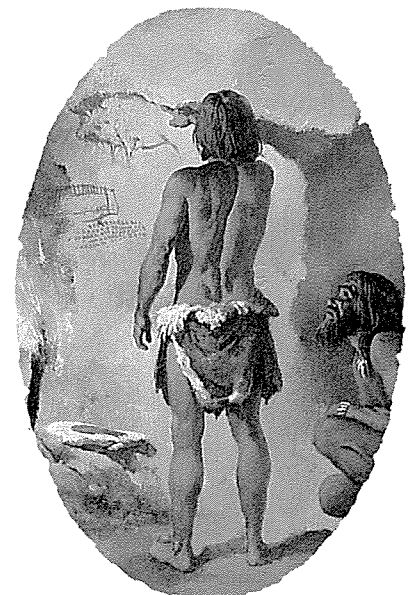
was some interbreeding with Neanderthals even if modern Man took over from them, exterminating them in the process. Modern Man had colonized most of the globe by 30,000 years ago. A great land bridge between Siberia and Alaska periodically emerged from the sea in the course of the last Ice Age, as sea levels rose and fell again. Human migrations into North America probably accompanied other predators such as lions and wolves, following herds of grazers such as bison, elk and mammoth.

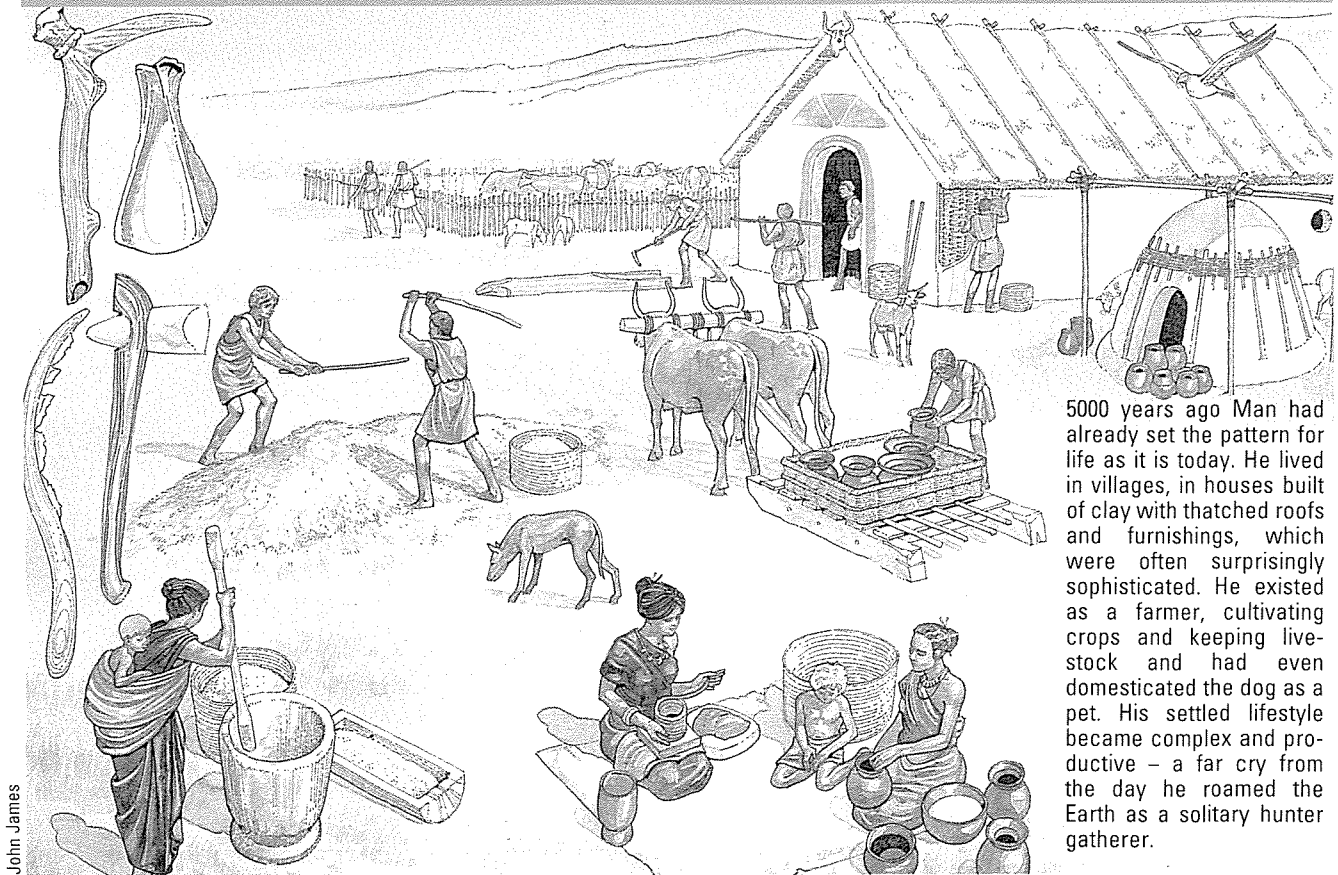
Man may have reached Australia as early as 50,000 years ago. But to



The cave painters seemed to go to great lengths to hide their art. One theory is that the paintings may have been done to invoke good luck and needed to be kept secret from hostile tribes.

Cro-Magnon man lived a mere 30,000 years ago. He looked quite similar to modern-day Man. Capable of manufacturing basic tools, he reached a high level of development.





John James

5000 years ago Man had already set the pattern for life as it is today. He lived in villages, in houses built of clay with thatched roofs and furnishings, which were often surprisingly sophisticated. He existed as a farmer, cultivating crops and keeping live-stock and had even domesticated the dog as a pet. His settled lifestyle became complex and productive – a far cry from the day he roamed the Earth as a solitary hunter gatherer.

do so – despite lowered sea levels due to the Ice Age – he must have made sea journeys between the islands that form a chain across the Timor Strait.

The last Ice Age ended 10,000 years ago, and the climate became generally warmer. Man was poised on the brink of one of the most significant developments in his history. For two million years or more, he and his antecedents had been hunters and gatherers, wandering through wide areas following game, sometimes using seasonal camps or caves as staging posts in nomadic wanderings.

Gradually, he had specialized in making certain tools, in hunting certain types of animal, in gathering certain plant foods.

His settlements became more sophisticated, and more permanent. A certain amount of crop cultivation was practised at scattered sites. In the Nile Valley, wild barley was cultivated at least 18,000 years ago, and horses had been domesticated in France 15,000 years ago.

The first town

At last, Man embarked upon full-scale agriculture. The first major centre was the high-rainfall Fertile Crescent of the Middle East, stretching between Jordan and Iran. The first settlements associated with farming were established 10,000 years ago: sheep and goat bones indicate stock farming.

Another sign of settled farming was the development of pottery. Populations increased fast. The first known town in the world was Jordan, situated in the south of the Fertile Crescent, with a population of some 2,000.

At the beginning of this agricultural revolution the entire population of the Earth was perhaps no more than 10 million: 8,000 years later, at

the beginning of the Christian era, it had reached 300 million, and was showing no signs of slowing down.

The settled life of farming, and the efficient control of food supplies, together with the support systems of a stable settlement, meant that far fewer infants died young from malnutrition and extremes of weather, and the old lived longer. The agricultural life also resulted in the first real accumulations of wealth in the form of food surpluses. It gave rise to the growth of trade, and the system of political alliances that would eventually lead to empire-building.

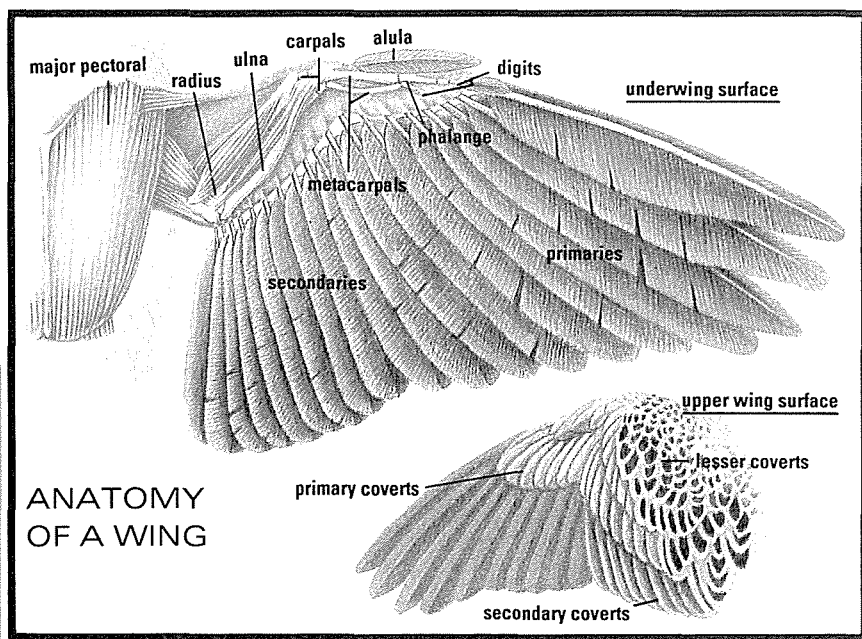


Paul Raymond

The Yanomami Indians are descendants of the earliest migrations to South America which took place 20,000 years ago. Their lifestyle has changed little for thousands of years.



Victor Englebert/Griggs Agency



NATURE'S FLYING MACHINES

Skidding along on its feet, a swan uses its body and wings as airbrakes after a rapid descent on to the water.

BIRDS, BEES AND BATS – ALL have evolved well equipped for flying, their skeletons perfectly adapted to aerodynamic necessities.

Birds are able to fly because of three important adaptations of their skeletons. First, they have an immensely strong but very light bone structure. Second, the skeleton has adapted to house relatively large and powerful chest muscles that work the wings. Third, the elongated 'arm' and 'hand' bones, making up the wing, are covered by a

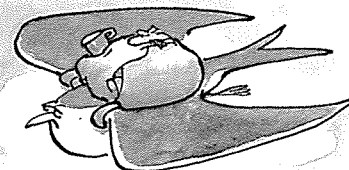
large surface area of close-fitting feathers – and it is feathers that are the key to flight.

Feathers are of immense importance to a bird – they complement the skeletal adaptations. Down feathers keep the bird warm, flight feathers enable it to fly, and contour feathers provide warmth, protection and coloration. Feathers are amazing structures, made up of a very light and rigid central shaft, which has small barbs projecting from each side. These barbs have tiny branches emerging from them called

Just amazing!

NEVER-ENDING JOURNEY

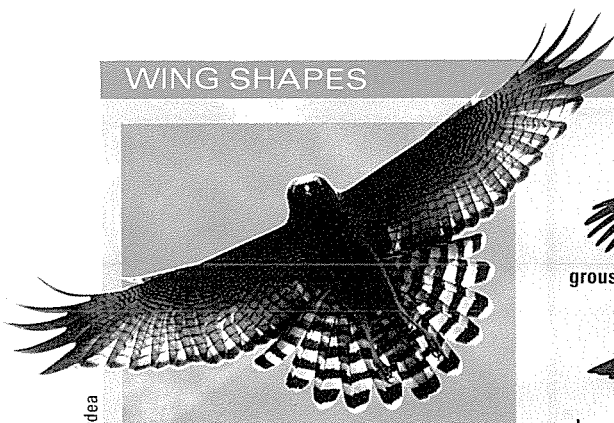
ONE BIRD, THE SOOTY TERN, CAN FLY FOR UP TO FOUR YEARS WITHOUT EVER LANDING ON SEA OR LAND, FEEDING AND SLEEPING ON THE WING.



Paul Raymonde



WING SHAPES



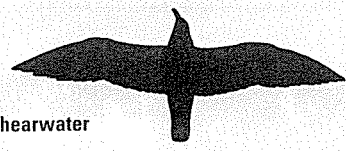
Hans and Judy Beste/Ardea

The wing shape of a bird in flight is one of the key features to identifying it. Birds' wings are adapted to their individual lifestyles. Grouse, for example, are essentially ground dwellers, only taking to the air if they sense danger. Their broad wings are ideal for rapid take-off. The shearwater is a glider – long thin wings enable it to glide effortlessly over the sea. The swift, on the other hand, needs manoeuvrability and its swept back wings and forked tail provide this. The eagle's broad wings give maximum lift and the spread out primaries control flight – essential for a species that lives by hunting. The slim, pointed wings of the falcon provide speed, allowing this species to travel at over 300 km/h, making it the fastest bird in existence.

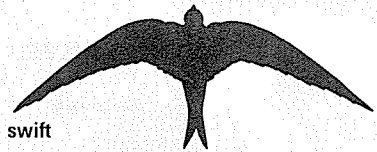
grouse



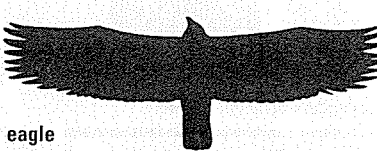
shearwater



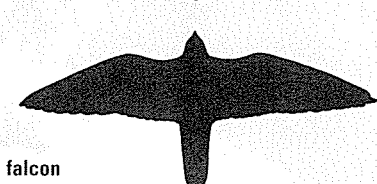
swift



eagle



falcon



feathers. These help to control flight at slow speeds – like wingflaps in aircraft. Turning is achieved by tilting the body and using the tail as a rudder.

Staying aloft

Because of their differing habits and life-styles not all birds fly in the same way. And different species have evolved different wing and body shapes. For example, swept back wings and forked tails are likely to belong to fast-flying birds that need to be highly manoeuvrable in the air – such as swifts, who catch their insect food on the wing. But birds with big wingspans are likely to be gliders, often seabirds, such as shearwaters.

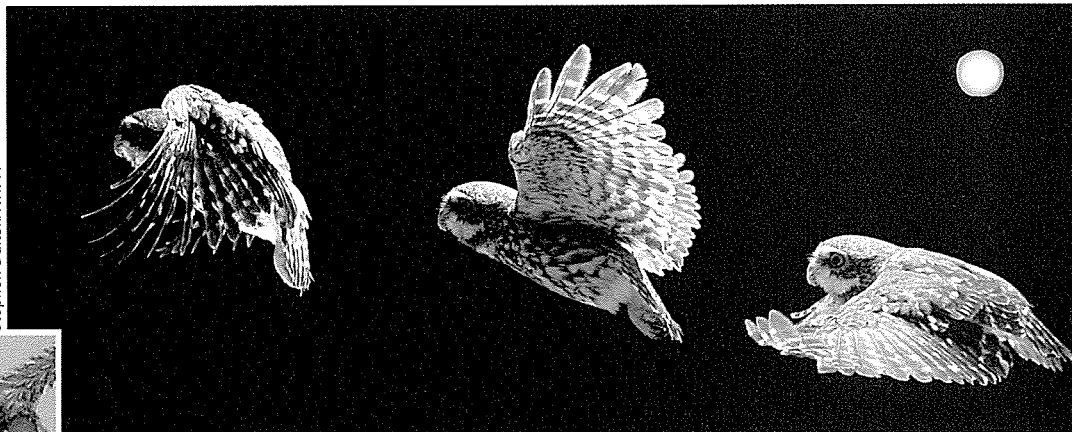
Some birds spend most of their time on the ground and take to the air only to avoid danger – gamebirds and rails belong to this group. Such birds have broad, rounded wings, which allow a fast takeoff and rapid acceleration, but do not permit sustained flight.

Long broad wings with spread primaries usually belong to soaring birds. These allow the birds to take maximum advantage of rising air currents, and so species such as eagles can fly for long periods, without having to use energy beating their wings to stay aloft.

Silence in flight is a prime requirement for a hunter of the night. Long bristles that extend beyond the feathers on the owl's wings eliminate any flapping sounds, enabling it to pounce on its prey without warning.

The sunbird is able to hover by putting all its flying effort into getting lift rather than forward movement.

Stephen Dalton/NHPA



barbules. The barbules are locked together, by means of tiny hooks (barbicels) and so the feather is united into one very smooth, very strong surface.

How birds fly

The feathers of the wings and tail control the bird in flight. Wings have three sets of flight feathers. The first group, the primaries, are used to move the bird forwards and control flight. The primaries are closed as the wing moves downwards, displacing a large volume of air – the power stroke. As the wing moves upwards, the primaries are opened out, so as not to cancel out the 'pushing' effect of the downward stroke.

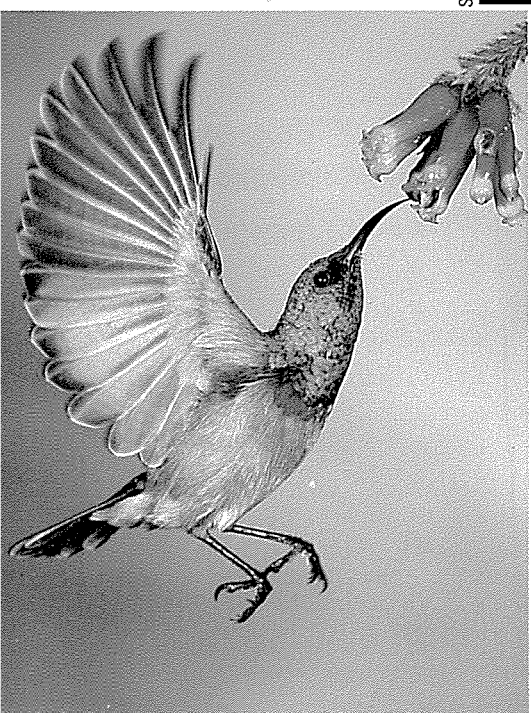
The next group of wing feathers are the secondaries, which provide lift. The third group are the alula

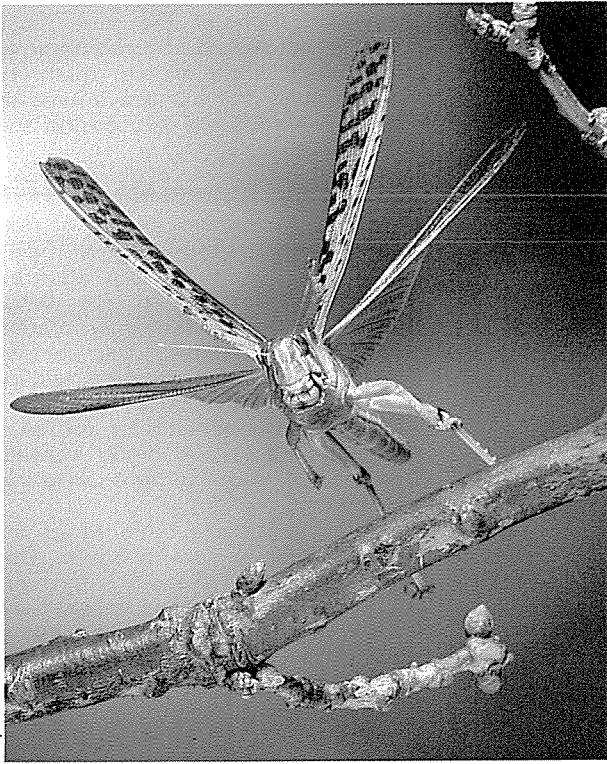
The most effective use of air currents, however, takes place over the sea. Because of frictional resistance between the air and the sea surface, the air in a wind travels slower, the closer it is to the sea. Large gliding birds, such as albatrosses and fulmars, use these conditions to sail in a series of regular circling movements.

They move down-wind losing height and then turn up-wind to gain height, by entering a faster moving layer. This all takes place within 20 metres of the surface of the sea and can continue for many hours with only occasional wing beats. Gulls following ships also make use of the local upcurrent created by the movement of the vessel.

Accurate determinations of the speed of bird flight are hard to

J. J. Brooks/Aquila





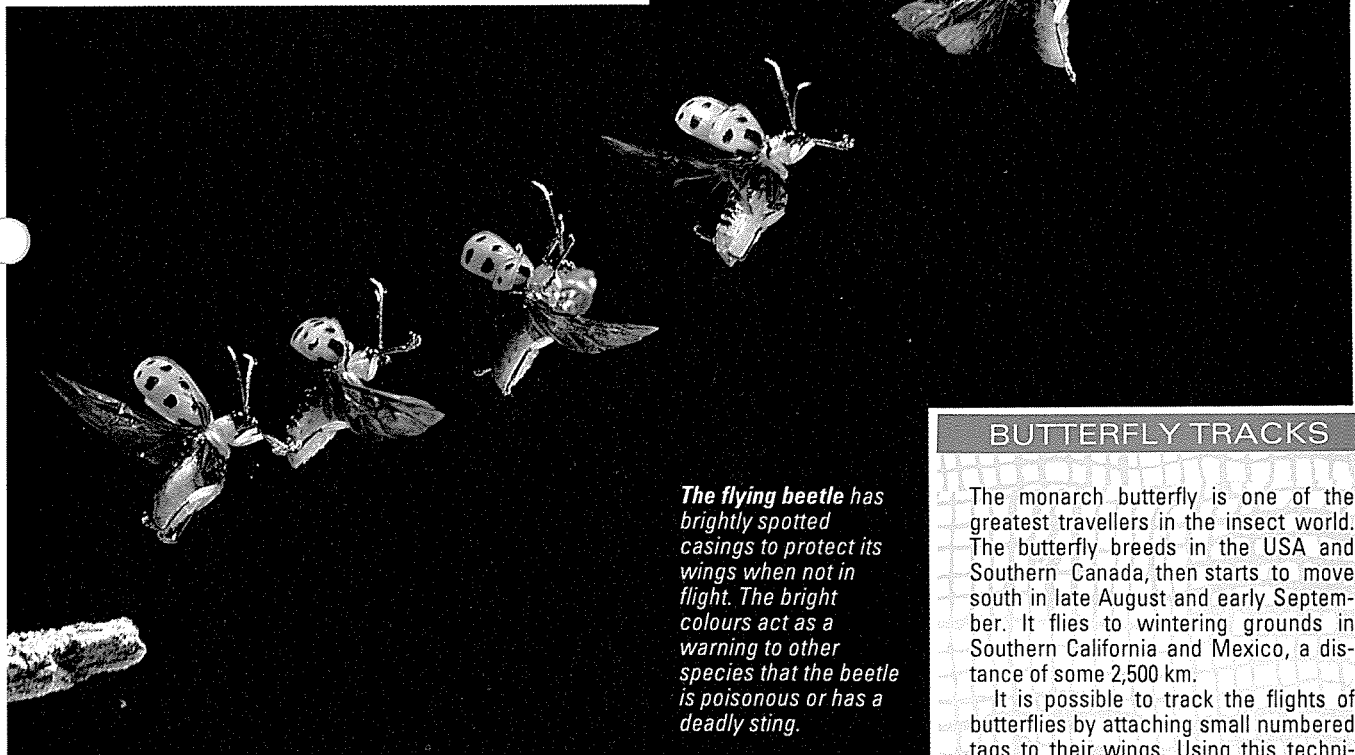
Stephen Dalton/NHPA

Locusts are the most destructive insects in the world, eating their own weight in food each day. In Ethiopia, one swarm took six weeks to destroy cereals sufficient to feed a million people for a year. The greatest swarm ever recorded covered 5,180 km.

so they can beat their wings rapidly.

The wing-beating record for insects is held by the midge, which beats its wings over 1,000 times per second. This compares with just 90 times per second for the South American horned sungem bird. The slowest insect wing beat is that of the Swallowtail butterfly at a mere five beats per second.

The rate at which energy is converted is called the metabolic rate.



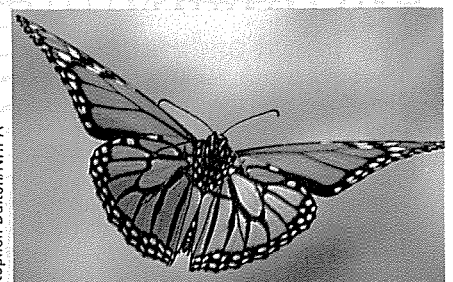
Stephen Dalton/NHPA

The flying beetle has brightly spotted casings to protect its wings when not in flight. The bright colours act as a warning to other species that the beetle is poisonous or has a deadly sting.

BUTTERFLY TRACKS

The monarch butterfly is one of the greatest travellers in the insect world. The butterfly breeds in the USA and Southern Canada, then starts to move south in late August and early September. It flies to wintering grounds in Southern California and Mexico, a distance of some 2,500 km.

It is possible to track the flights of butterflies by attaching small numbered tags to their wings. Using this technique, a single monarch butterfly was found to travel 1,700 km in just 18 days, an average of nearly 95 km per day. One monarch tagged in Texas was found two days later over 400 km away.



Stephen Dalton/NHPA

obtain. The smaller perching birds, such as sparrows, fly at between 30 and 50 km/h, while migrating ducks may reach speeds of around 80 km/h. The normal speed of a racing pigeon is also thought to be around 80 km/h. The fastest of all birds is said to be the peregrine falcon. An experiment carried out in Germany has shown that a peregrine reaches speeds of between 270 and 320 km/h when swooping on prey.

As a result of sightings from aircraft and radar, there is more information available about the heights at which different birds fly.

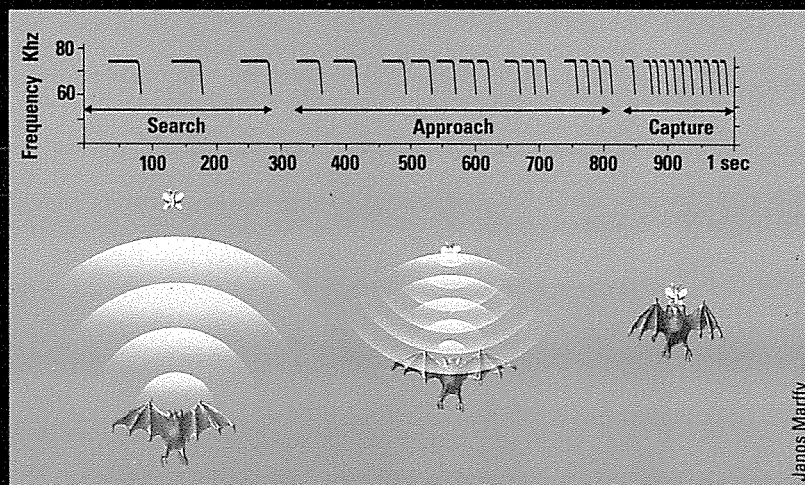
Most birds keep well below 150 metres during normal local movements, but they may fly much higher during migration. Migrating wading birds have been observed at heights of at least 6,000 metres. Smaller migrants, such as perching birds, cannot reach such heights — they rarely fly above 1,500 metres.

Flying insects

Another important group of natural fliers are insects. They have very efficient bodies for flight. Their short, thick muscle fibres and short connecting nerves transmit impulses to the muscles very quickly



EAR-SIGHT



Most bats have very small eyes, sometimes as tiny as a pinhead, capable only of distinguishing between light and dark, but incapable of determining shapes or patterns. Instead, they plot their path through the night and locate their prey using a system called echolocation. The bats produce very short, high frequency sounds, inaudible to the human ear, through their mouths, and their ears intercept the echo of the reflected sound waves. A sound picture is thus communicated to the bat. With some bats, the sound is emitted through their nose, with flaps around their nostrils used as a megaphone. The accurate sound pictures bats receive enable them to fly round obstacles as thin as a piece of string without touching them and search out prey in almost total darkness. Bats also produce other sounds that can be detected by the human ear.



Flying insects can turn stored energy into movement at a much greater rate than any other creatures. A human athlete can increase his metabolic rate by about 20 times, but only for short bursts. An insect can increase its metabolic rate by ten to 20 times and sustain it for several hours. An insect can even reach 50 times its normal metabolic rate for short periods.

Flight endurance

Insects store most of their energy as fat, so the proportion of fat carried by an insect determines its flight endurance. For example, a locust with fat comprising 15 per cent of its body weight will be able to keep flying for about 20 hours. A locust with half the amount of fat would be forced to land after just ten hours.

The method by which birds and insects navigate is not yet fully understood. Birds are known to have a magnetic sense which gives them a sort of internal compass. They also use the positions of the sun and stars.

Insects have prominent, bulging, compound eyes, made up of many individual facets, each of which has its own small lens. This enables the insect to build up a mosaic picture of its surroundings.

Some compound eyes, those of the housefly, for example — have thousands of individual facets. However, the image seen by an insect is nowhere near as detailed as that seen by a bird or a mammal.

Experiments have shown that insects use the position of the sun for navigation, even when it is cloudy. They do this by detecting the plane

of polarization of the sun. They must also have an accurate internal body-clock that allows them to compensate for the movement of the sun across the sky during the course of the day.

Flying mammals

The only mammals capable of true flight are bats, although other mammals, such as the flying squirrel, can glide from tree to tree. Bats' wings are large elastic membranes that stretch between the slender arms, legs and tail, and held rigid by elongated 'fingers'. The wing membrane is an extension of the skin from the back, and blood vessels keep it well supplied right up to the extremities.

During flight, the bat's wings do not flap merely up and down. The two front tips of the wings form an elliptical circle in the air as they move down to the back, come forward in front and rise up above the head again.

Depending on their size, bats can make from 12 to 18 wing strokes per second. Once it has gained speed by beating its wings, a bat can also glide along.

RACING PIGEONS

Pigeon racing developed from the use of homing pigeons for carrying messages — a practice that originated in Roman times. Today's specialized racers are descended from the rock dove, a species once domesticated as a source of food. The rock dove is not a migrator, travelling only as far as is necessary to find a meal. Yet today's racing pigeons have been known to fly distances of almost 2,000 km. Scientists have established that the birds find their way home using an internal compass, and the position of the sun during the day and the stars at night. How the birds establish their starting location when they are transported in closed baskets remains a mystery.



THE PREDATORS

The piranha (left) is able to snap off human fingers and toes with its powerful jaws. The rattlesnake (below) is poised to strike, with venom already seeping from its fangs. The venus fly trap (right) slowly crushes its victim to death.

Stephen Dalton/NHPA

M. Freeman/Bruce Coleman Ltd.

THE POISONERS TEETH AND CLAWS MANEATERS

UNLIKE HUMANS, MOST creatures kill only for food or in self-defence. Even so, in many instances, their survival depends on their ability to kill – by slashing, biting, crushing, stinging or even electrocuting their victims or attackers.

Among the land mammals, some of the most impressive predators are the big cats. When a lion or tiger pounces, its lethal combination of claws and teeth can bring death to its prey within seconds.

The lion's paw becomes an instrument of death when the muscles straighten.

The claws, normally withdrawn into sheaths to keep them sharp, are dug into the victim to bring it down, then the cat bites through its neck to sever the spinal cord.

Big cats hunt a variety of prey, from small mammals to goats, cattle, zebra and buffalo, but only three species – the lion, the tiger and the leopard – are known to become man-eaters. Not many do, but once they get a taste for human flesh the results can be devastating. In Nepal and northern India, a tigress called the 'Champawat Man-eater' killed 438 people in eight years, before she was cornered and shot.

The largest of the big cats is the Siberian tiger, which can weigh up

to 300 kg, but this is small compared with some species of bear. Like the big cats, bears kill with their teeth and claws and will attack a human if they feel threatened.

In terms of average adult size, the biggest bear is the Kodiak or Alaskan brown, which measures some 2.44 metres from nose to tail and weighs up to 675 kg. However, the polar bear – the only large land animal that will track and kill a man for food whenever the opportunity arises – has been known to reach a weight of over 1,000 kg.

Death in the water

The most notorious aquatic killers are the sharks, but there are many other underwater assassins. In fresh water, the deadliest are the cannibalistic piranhas, which live in the rivers of South America.

These are fairly small fish, usually 30 cm or less in length, but they have immensely powerful jaws with razor-sharp teeth and they attack in gangs. Like sharks, they can sense the blood or the struggles of an injured creature in the water, and they can reduce an alligator to bare bones in less than five minutes.

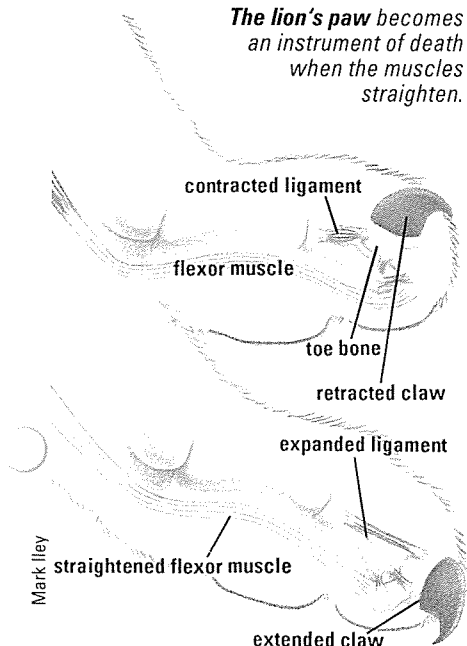
The marine equivalent of the piranha is the bluefish, which is found in most warm seas. Bluefish wander the oceans in huge shoals, attacking anything edible that comes their way. They have even invaded beaches and attacked



A lioness in the final stage of the kill. Having caught a wildebeest, she bites into its throat until it suffocates to death.

Gunter Ziesler/Bruce Coleman Limited

Jane Burton/Bruce Coleman Limited



swimmers. The bluefish's killer instinct is so strong that during a feeding frenzy it will eat until full, vomit, and start all over again.

Although most predatory fish use their teeth to catch and kill their food and to defend themselves against attack, some have extra weaponry. Most rays, for instance have thorn-like spines along their tail which can inflict a painful wound on an attacker.

Stings and shocks

In some species, the stingrays, for instance, these spikes are venomous, and many swimmers have suffered painful and even fatal stings from these fish.

Some other rays use electric shocks to stun their prey. The electricity is generated by specialized muscle cells on each side of the fish, and a large torpedo ray can give a considerable shock.

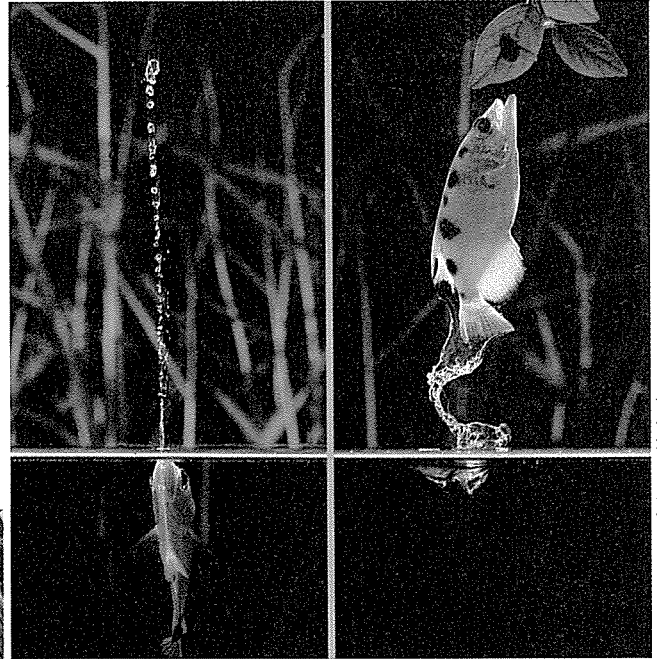
The most powerful electric fish is the freshwater electric eel, another hazard of the rivers of South America. It can deliver a massive shock,

strong enough to kill a man.

For centuries, travellers to the jungles of South America have reported giant snakes, anacondas, measuring over 30 metres long. But despite these reports, the longest anacondas recognised by scientists are between eight and nine metres, and the longest snake known is the

An archer fish shoots an arrow of water with deadly accuracy at its next meal – a low flying insect. Alternatively it may use its powerful muscles to leap out of the water.

A rock python devours a gazelle head first, after squeezing the animal to death with its muscular coils. A meal of this size can last a python for weeks.



Kim Taylor/Bruce Coleman Limited

directly into the victim.

These front fangs may be short and fixed, like those of the cobras and sea snakes, or long but hinged, like those of the vipers. The latter can be folded back against the roof of the mouth when not in use.

Snake venom usually acts on the victim's central nervous system, causing paralysis and then death. The potency of the venom varies from one species to another, but it is always strong enough to kill the snake's normal prey. Its effect on larger creatures, which the snake

reticulated python of southeast Asia, which can reach 10 metres in length.

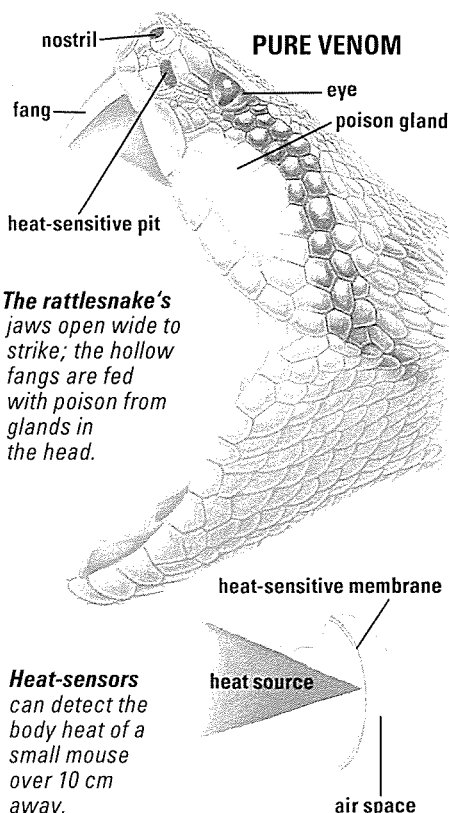
Deadly reptiles

Anacondas and pythons belong to the group of snakes called constrictors, which kill their prey by suffocating it. They can kill and eat animals as large as pigs, goats and antelopes (and children or small adults), by holding them with their mouths and then coiling themselves tightly around them so that the victim cannot breathe.

When the unfortunate victim's struggles have finally ceased, the snake swallows it whole, a process that can take several hours. After such a meal, the snake may not eat again for weeks or even months.

Most snakes eat smaller meals, however, and feed more often. Some simply grab and swallow prey such as mice and frogs, but many use poison to kill or immobilize their food before they eat it.

When a poisonous snake bites, venom from poison glands in its head flows down, or through, specially adapted fangs in the upper jaw and into the victim.



Mark Iley

Just amazing!

THE CROAK OF DEATH

COLUMBIAN INDIANS DIP BLOWPIPE DARTS IN POISON FROM THE GOLDEN DART POISON FROG – POISON FROM ONE FROG CAN KILL 2,200 PEOPLE.



Paul Raymonde

THE PREDATORS

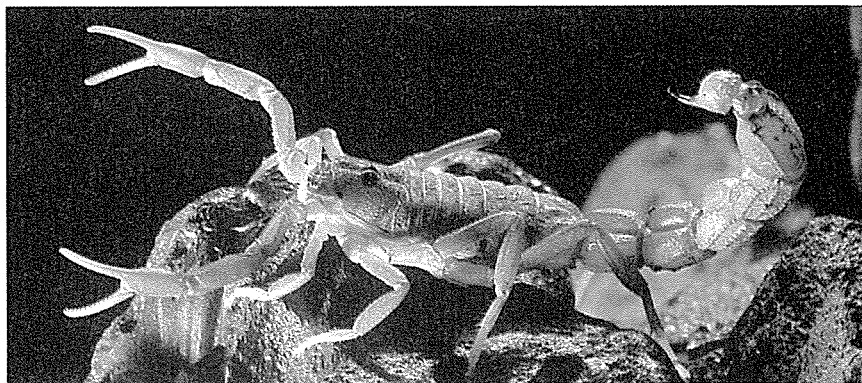
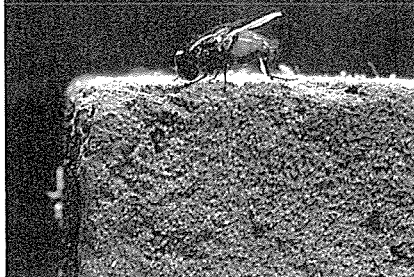
makes it impossible for the bee to pull it out of its victim after stinging.

Because of this, a bee will only sting as a last resort, usually when it is under attack itself or when it is defending its hive. Some bees, however, seem to feel threatened more readily than others and as a result they act very aggressively.

Some of the most aggressive bees are found in Africa. These also produce a lot of honey, and in 1956 some 170 queens were imported into Brazil to be cross-bred with docile local bees to improve their honey production.

It was thought that the resulting hybrids would combine the honey-making ability of the African bees with the docility of the Brazilian

The jumping spider uses its eight eyes to monitor the approach of its prey. Then the spider pounces on its victim.



Scorpions sting their victims with their tails. The animal is then held in its claws and sucked into the scorpion's mouth.

bees. As it turned out, the hybrids were perhaps even more aggressive than their African cousins, and a year later 26 queens and their swarms escaped.

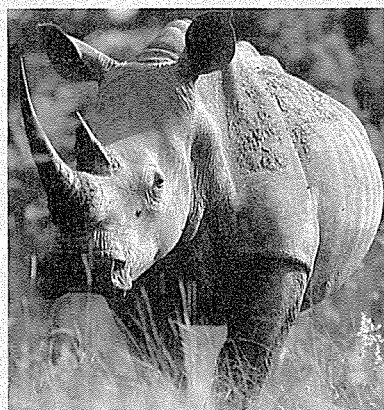
They multiplied rapidly and began spreading northwards at a rate of over 300 km a year. The swarms have so far killed about 200 people and injured many more in their relentless drive towards the USA — they inspired a number of disaster movies such as 'The Swarm'.

Jane Burton/Bruce Coleman Limited

will bite if it feels threatened and cannot escape, depends on such factors as the nature of the venom, the amount injected and the size and health of the victim.

The most powerful snake venom is produced by one of the many species of sea snake found in the Pacific Ocean. The venom of this snake is 100 times more potent than that of any other species, but fortunately it is a mild-mannered beast and will only attack a person if provoked. When it does bite, it

HORNS AND TUSKS



Many animals defend themselves with horns, antlers or tusks. Rhino horns are made of a kind of compressed hair and grow throughout the life of the animal. The antlers of deer are made of a material similar to bone, and are usually shed and regrown every year or so. Elephant tusks are elongated upper incisor teeth, which do not regrow.

often does not inject much venom, so the bite is not always fatal.

On land, the most dangerous snake is probably the saw-scaled viper of Africa, the Middle East and India. Just three milligrammes of its venom are enough to kill a human being. This viper is also unusually aggressive when disturbed — unlike most other snakes, which prefer to escape when frightened.

Spider bites

Snakes are not the only creatures that inject poison by biting. Most of the 30,000-odd species of spider have a venomous bite, and some of these are dangerous to humans. Amongst these are the well-known tarantulas, funnel-webs and black widows, and a Brazilian spider, *Phoneutria fera*, which is the most aggressive and toxic of them all —

just 0.1 milligrammes of its venom can kill an adult human.

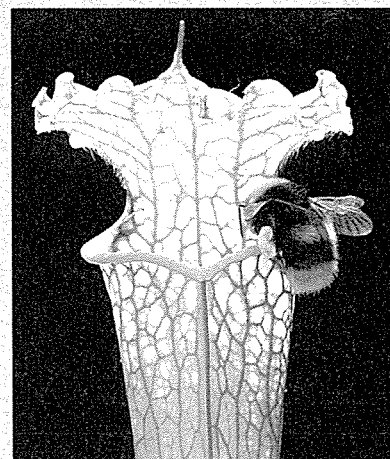
Spiders belong to a group of creatures called the arachnids — a group that also includes the scorpions, which sting with their tails rather than by biting.

The sting in the tail

Scorpions, like wasps and bees, have a poison gland and a sting in their tails. Scorpions and wasps use their stings as a hunting weapon as well as for defence, but a bee does not kill to eat and its sting can be used only once. Unlike the smooth sting of a scorpion or wasp, the sting of a bee has a barb, which

KILLER PLANTS

Many plants contain poisons or other unpleasant substances, which deter animals or insects from eating them. But some plants go further, and actually capture and eat insects that land on them. The insects are trapped on or within the leaves, then enzymes produced by the plant digest them and they are absorbed into the plant. The Venus fly trap has hinged leaves that snap shut to imprison any insect landing on it and the sundew has sticky hairs on its leaves that curl round any insect unlucky enough to get stuck to them. The pitcher plant (right) has vase-like leaves with a digestive liquid at the bottom. This digests any insects that fall in down the slippery insides of the leaves.



Michael Vard/Bruce Coleman Limited



Jen & Des Bartlett/Survival Anglia



The Tawny Frogmouth is a nocturnal bird, which feeds on insects and small animals. At night they crowd together, during the day they sleep in pairs in trees. If the bird senses danger it will stretch its head and neck upwards and stiffen its body so it blends in with the tree.

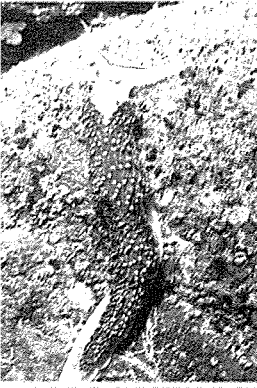
Gerald Cubitt/Bruce Coleman Limited



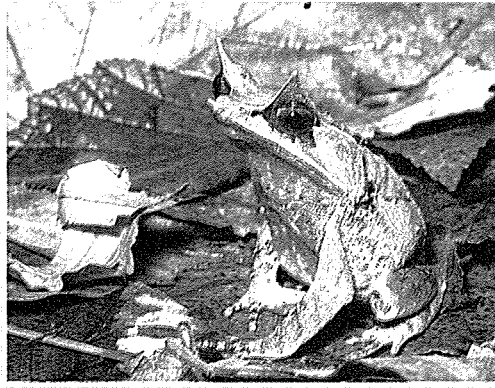
Leaf insects are relatives of the stick insect. The body and legs are flattened to mimic the leaf on which the insect feeds. It even goes so far as to bear leaf-like veins and a withered look around the edges of the wings. These insects are found in the Tropics.

Sea slugs are often brightly coloured to warn predators that they may be poisonous. Some have adopted the colouring of their diet of seaweed and algae.

Jeff Foot/Survival Anglia



Michael Fogden/OSF



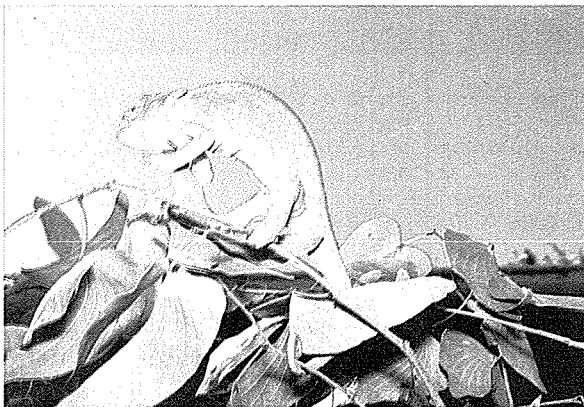
The Horned Frog pushes its body into the undergrowth to become all but invisible as it lies in wait for a passing mouse or lizard.

Jeff Foot/Bruce Coleman Limited



Monarch butterflies have bright colouring – nature's warning that they may be poisonous. Other butterflies mimic the Monarch's colouring.

Jen & Des Bartlett/Survival Anglia



Chameleons change colour when impulses from the spinal chord are transmitted through nerve fibres to melanophore cells, which then disperse a black pigment.

Mary Grant/Bruce Coleman Limited



The tiger's striped coat blends well with the strong shadows of the trees and tall grasses found in its jungle habitat.

Jen & Des Bartlett/Survival Anglia



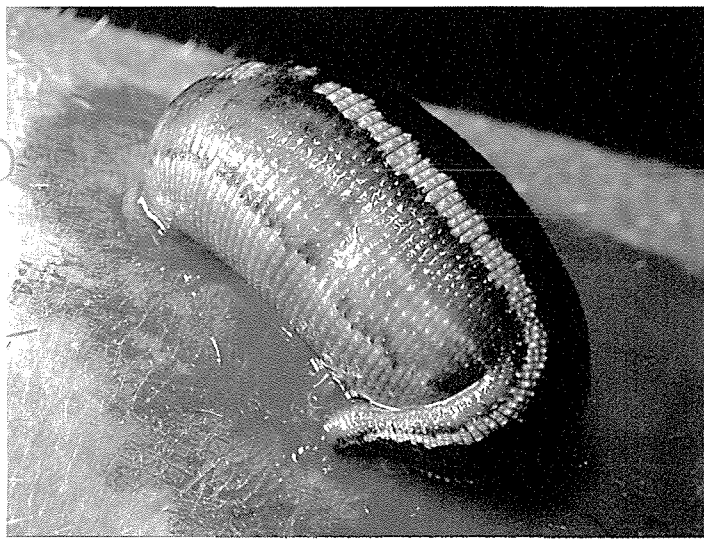
The Ptarmigan adopts seasonal plumage – mottled brown to match the undergrowth in the summer and white to blend in with the snow in winter.

The Zebra's stripes may not appear effective camouflage as it wanders around the scrublands, but when seen through the eyes of predators with no colour vision, they blend almost totally with the branches and bushes that surround them. Travelling in herds also affords protection.

R.I.M. Campbell/Bruce Coleman Limited



WEIRD DIETS



Bruce Coleman Limited

Food comes in many forms for animals, from human blood for the leech (above) to poisonous snakes for the mongoose.



THINK OF SOMETHING – anything – and there will be an animal that eats it. Termites eat wood, worms eat earth, mice eat soap, the honey guide bird eats beeswax, rabbits eat their own droppings and cockroaches eat everything, including photographic film.

Leeches suck animals' blood and so does the vampire moth. Birds of prey are usually thought of as meat-eaters, but the Everglades kite feeds on an exclusive diet of water snails, while the palmnut vulture is entirely vegetarian, eating African oil nuts. Most parrots feed on fruits and seeds but the kea, a New Zealand parrot, has a taste for carrion and feeds on dead sheep. Some male butterflies suck roots to extract the sodium that they need to produce sperm.

Some female insects eat their partner while they are mating. Having fertilized the female praying mantis, the male becomes a nourishing meal that will help her produce plenty of eggs. The male empid fly, however, avoids this fate by presenting the female with another insect to eat while they mate.

Even poisonous species are considered a delicacy by certain creatures. The deadly Portuguese man-o'-war is devoured by the ocean sunfish which is immune to its poison. Poisonous rattlesnakes also have their enemies. The king snake – immune to rattler venom – chokes the rattler to death and swallows it whole.

Battles between the cobra and mongoose are legendary. The mongoose, which is not immune to cobra venom, avoids the cobra's fangs as it lunges at it and closes in for the kill. It eats the snake, having (it is thought) first removed the poison glands. Similarly the bee-eater wipes a bee on a branch to squeeze out its sting before swallowing it.

You are what you eat

Much of an animal's appearance and taste is determined by its diet. Lesser flamingos get their colour from chemicals in their food; if captive flamingos are fed on the wrong diet, they turn white rather

The bee-eater thrives on ants, wasps and bees – but skilfully crushes out their stings first.

than pink. Herbivores (plant-eaters) are generally tastier (to humans) than carnivores (meat-eaters). The vegetarian green turtle, for instance, makes excellent soup, while broth made from the carnivorous leatherback turtle tastes disgusting. The eggs of many seabirds, such as the cormorant, have a strong fishy taste because of the birds' diet.

The amount animals need to eat varies enormously. A tortoise is recorded surviving on one banana a

Brian Rogers/Biotopos



month, while the Okinawa habu snake can reportedly survive for three years without food. The blue whale, on the other hand, eats about four tonnes of krill a day – one fortieth of its own weight. The mole, which paralyses live worms with a bite and then stores them, eats its own weight in worms every day.

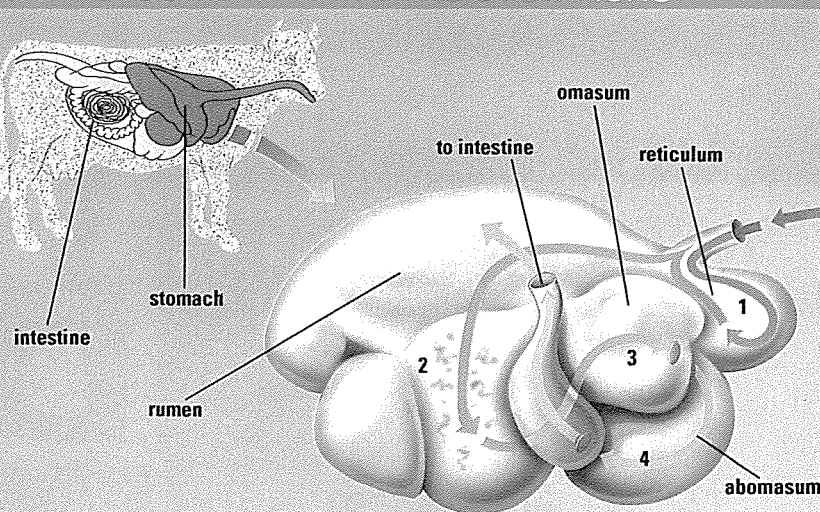
Super stomachs

The giant panda must also eat regularly. It spends about 16 hours a day eating up to 18 kg of bamboo – its only food. It eats so much because it has a poorly adapted intestine.

Most plant-eaters have an intestine 25 times their own body length coiled up inside, but the panda's is only five to six times its body length – a length more typical of a meat-eater. Plant-eaters have long intestines because the cellulose in plants is hard to digest. Cows, for instance, cope with this digestive prob-

Nature Photographers Ltd.

IN AND OUT OF THE COW'S STOMACHS



To digest the tough cellulose content of grass, the cow first gives it a quick chew, then passes it through the gullet into the reticulum (1). Here, it is formed into balls of cud which are returned to the mouth for a longer chew. The re-chewed grass is then passed on to

the rumen (2) where bacteria break it down. Next, it is filtered through the omasum (3) to the abomasum (true stomach) (4), where enzymes break it down into nutrients. The rest is passed into the intestine to be absorbed into the blood or excreted.

Chris Lyon

lem by having four stomachs.

Animals have some unusual ways of finding food. Dung beetles, using their sense of smell, home in towards buffalo dung as it hits the ground. Oilbirds, which have a system of sonar navigation like bats, locate fruit at night by smell.

Dolphins use sonar clicks to locate shoals of fish. The pit viper has a sophisticated method of heat detection which enables it to locate and home in on unseen warm-blooded mammals at night. Frog-eating bats that hunt by sound, distinguish edible frogs from poisonous ones by their mating calls.

The green heron uses bait to attract fish within striking distance

by dropping an insect on to the surface of the water. The alligator snapping turtle has a 'worm' (actually a knob of pink flesh) inside its mouth which lures fish into its jaws.

Bees, however, work hard. They make nearly 65,000 trips and visit 45–65 million flowers to produce 1 kg of honey. And a large colony with 80,000 workers eats up to 225 kg of its own home-produced honey each year.

A colony of leaf-cutter ants can strip a fruit tree bare of leaves overnight. But when it comes to sheer destructive power, there is nothing to equal the dreaded locust. A large swarm can chomp its way through 80,000 tonnes of grain and vegetation a day.



Foxes have lost much natural hunting ground to towns – now they must forage where they can.

THE RE-CYCLING EARTHWORM

As the earthworm eats its way through the soil, it performs a most valuable ecological service. Some species form a U-shaped tunnel into which they draw organic matter from the surface to eat, along with some earth. The gizzard grinds this down and after digesting



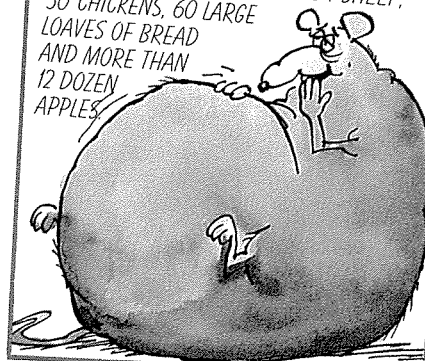
Heather Angel

nutrients, the mineral waste is evacuated back up the other end of the tunnel to form the familiar earthworm casts (above). In this way, earthworms may turn round up to 5 tons of soil for every 1,000 sq metres each year, enriching it with the valuable minerals and nitrogen in the ground-up soil they excrete.

Just amazing!

AND COFFEE TO FOLLOW

THE SHREW AT ONLY 2 GM, EATS THREE TIMES ITS OWN WEIGHT IN FOOD EACH DAY. THIS IS THE EQUIVALENT OF AN ADULT MAN OR WOMAN EATING 1 SHEEP, 50 CHICKENS, 60 LARGE LOAVES OF BREAD AND MORE THAN 12 DOZEN APPLES.



Paul Raymond



BREEDING THOROUGHBREDS



Flat racers usually race as two and three-year-olds, after that many become steeple-chasers where strength and stamina are needed to cover the much longer and more strenuous courses.

Trevor Jones/Allsport

- MATING THE BEST
- A TRAINER'S JOB
- STUD FARMS

RACEHORSES, GREYHOUNDS and racing pigeons are the athletes of the animal world and are as carefully trained as any human athlete. Many, indeed, have more time, care and money lavished on them than most human athletes, which is scarcely surprising as these racing animals are big business.

Animals differ from human athletes because they are selectively bred for success. The basis of all breeding is that the offspring inherit characteristics from their parents and the hope is that they will inherit the best characteristics of each parent. They may also, of course, inherit the worst. To that extent, breeding is potluck. The science of breeding — an inexact science — lies in the continued mating of good animals (and good animals *only*) through several generations to produce excellent offspring that are most likely to be winners. It is important to introduce new blood (unrelated animals) to the family (the bloodline) because the mating of animals that are closely related leads to inbreeding and the develop-



Coloursport

ment of physical and temperamental weaknesses.

Horses have been bred and raced ever since men first climbed on their backs. The real breakthrough came with the development of the British thoroughbred in the early 1700s. At that time Arab horses were the best racers in the world. Three Arab stallions — the ancestors of many of today's winners — were imported and mated with English mares. The result of these Arab-English crosses was some outstanding racehorses able to beat the best pure Arabs.

Introducing Arab blood to the heavier English horses was a breeding success, producing fast, strong horses — thoroughbreds — that combined the best aspects of both

Greyhounds must be 15 months old to race; they usually reach their peak when two and a half or three years old. Few race over the age of five.

parents: the speed of the Arabs with the stamina of the English. New bloodlines were started and these continue today, although breeders are constantly seeking to improve on them by introducing new blood from thoroughbreds elsewhere in the world.

● Training a winner

The story of a great classic winner generally starts at a stud farm where stallions are put to mares. Every horse has its own pedigree





Animal Health Trust

A mechanical treadmill is used in a controlled environment to help vets to study horses in planned patterns of exercise for carefully calculated periods of time.

(parents, grandparents and so on) recorded in a studbook and each owner will select a mate on the basis of its racing performances, conformation (shape) and pedigree. The resulting foal will generally be sold on at the autumn sales as a yearling – a horse that has yet to see two Januaries (Northern Hemisphere) or two Augusts (Southern Hemisphere).

At this stage the horse is an unknown quantity: a half-tonne,

Equine pools can be a boon when dealing with a horse which has sustained an injury. Swimming allows the horse to continue exercise without putting too much strain on its legs. The pools are also used to treat horses who are severely afflicted with arthritis – some have recovered to the point of returning to winning form.



Laurie Morton

million-pound baby that has never been saddled. The trainer's job is to turn the gangly youngster into a racehorse, first breaking it to the leading rein and saddle, then schooling it to trot, canter and finally gallop.

Not until its first race as a two-year-old will the owner and trainer have an idea of the true value of their prodigy. Only the very best will go on to win one of the classic races open to three-year-olds and upwards. Some flat racing horses continue racing until the age of five.

Greyhound racing

The greyhound, bred by man from a wolf-like ancestor, is first recorded being owned by Solomon around 1000BC. However, the modern sport of greyhound racing dates only from 1926 in Britain, having started in 1921 in the USA.

A champion sire, from whom champion racers are bred, is unlikely to produce sons who are also great sires – though it can do if mated to the right bloodlines. The capacity to be a champion sire, as opposed to a champion racer, often skips several generations. Typically the fourth generation – the great-great grandson of the original champion sire – turns out to be a champion sire when mated with a suitable bloodline. The outstanding conjunction of two bloodlines or crosses (a cross is where both the

great-great grandson and the dam he mates are descended from the same dog; that is, one bloodline) is known as a 'nick'. This is what all breeders are looking for because the offspring will more than likely be winners on the track. The same applies to champion dams.

Pigeon racing is now an international, multi-million pound business with its own profitable stud farms.

CLEVER PLOYS

A bird with a mate on eggs will race back quickly. Birds are allowed to lay three clutches a year but only two are allowed to hatch. The third clutch is boiled to kill the embryos and returned to the nest. A live chick is slipped under a bird sitting on dead eggs to encourage its mate to speed back.

Those who breed seriously are looking for three things when buying a stock bird: performance, pedigree and a successful breeder behind the bird.

Different breeders have their own criteria for selecting potential winners from which to breed. Commonly, though, they are guided by a good eye ring around the pupil, a well-feathered keel and a quiet heartbeat that can barely be detected. The birds must also be in good health with excellent plumage.



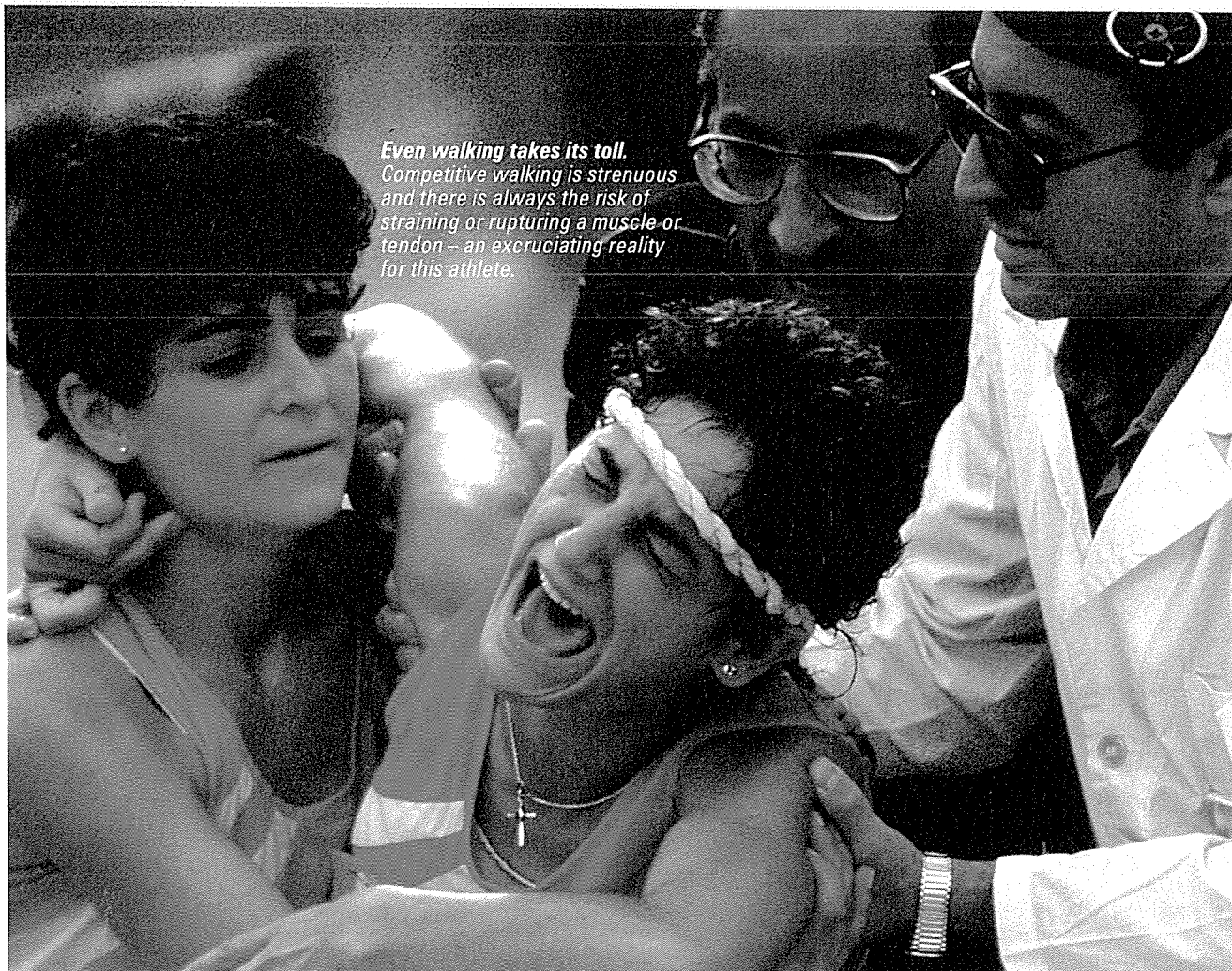
Pigeon racing is big business these days and some birds fetch thousands of pounds.

Prize pigeons are released en masse from a huge custom-built transporter – a far cry from days past when each owner would release his own bird. Exactly how pigeons navigate their way home is still unexplained.



Evelyn Photos





Even walking takes its toll.
Competitive walking is strenuous and there is always the risk of straining or rupturing a muscle or tendon – an excruciating reality for this athlete.

SPORTING HAZARDS

MUSCLE STRAIN

A BOXER'S DAMAGED BRAIN is probably the worst consequence of a sporting activity, but most athletes risk some damage through misuse of their bodies or through repeated exertion.

Such injuries can happen simply by overstraining – putting too much stress repeatedly on the same joint, limb or muscle; or they can be the result of an accident; or the deliberate intention to injure on the part of an opponent.

Some injuries happen because a

BREAKING BONES

muscle, tendon, ligament or bone becomes overstressed either over a period of time or in one cataclysmic spasm in striving beyond the body's breaking point.

Muscle injuries, known variously as a pull, strain or tear, usually involve some or all of the muscle fibres and connective tissue. The severity is classified according to the amount of tissue involved. Often, the cause is sudden exercising of a muscle before it is properly warmed up. Cold muscles do not contract smoothly and hence over-

REHABILITATION

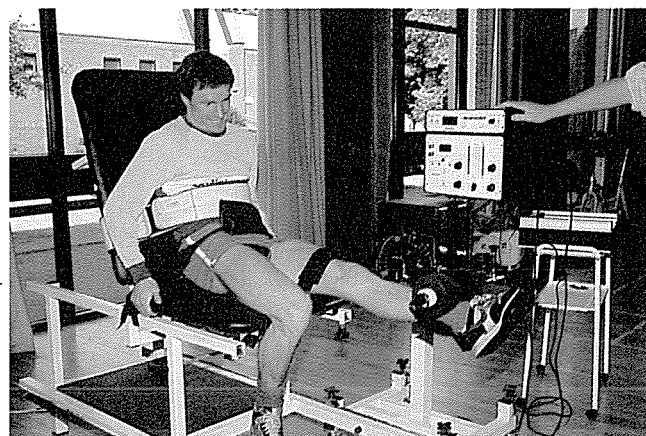
load some fibres. Fatigue and over-stressing a muscle to produce more force than it is capable of can also cause injury. A sudden shooting pain is a sure indication. Tendons, the fibrous ends of muscles that join on to bone, can be torn by direct blows or become inflamed through over-use.

Bone fractures

Stress a bone too much and it can crack or break. When the two ends of a bone are separated from each other, it is known as a complete fracture. When slight cracks occur in the surface of the bone, it is known as a stress fracture.

Complete fractures are most common in the long bones of the arm and leg, whereas stress fractures usually occur in the small bones of the feet and hands.

Footballers and skiers can suffer from broken legs, while rugby players risk breaking their collar bone in a tackle. Cricketers are prone to broken fingers, ribs and arms. Stress fractures can be caused by



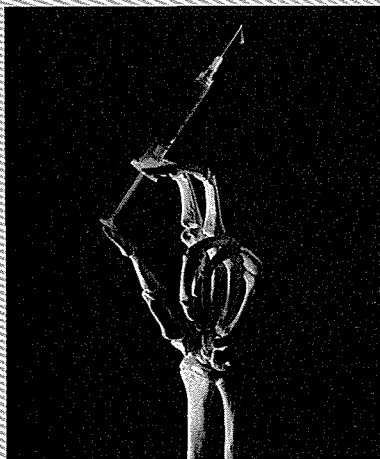
After the injury, the cure. Highly specialized equipment is used to treat sports injuries, as at this rehabilitation centre, where a footballer's recovery is monitored while he does remedial exercises.



training over long distances continually – especially over hard surfaces – or by increasing the intensity of training.

Most serious of all are open fractures, in which the broken end of the bone protrudes through the skin, or if a wound reaches down to

STERIOD ABUSE



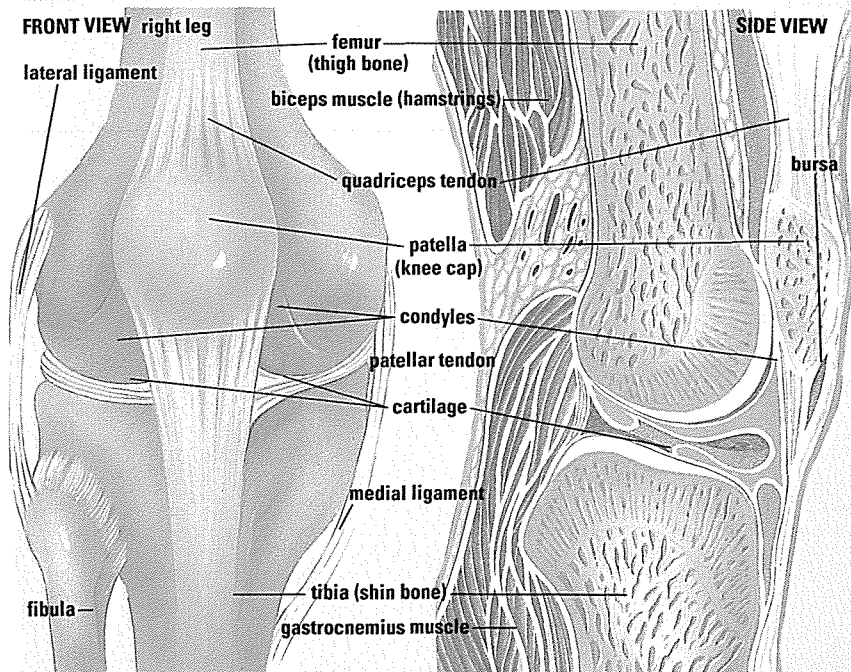
Some athletes take anabolic steroids to increase muscle power, aggression and speed recovery from training. All sports bodies disqualify those who test positively. Taken continuously, even over the relatively short career of a top athlete, anabolic steroids may result in:

- Liver disorders
- Impotence
- Greater risk of heart attack
- Mental disorders

it, creating the risk of infection.

All athletes warm up before embarking on their sport. Warming up stimulates blood circulation so that the heart is not stressed by a sudden demand on it. It also raises the temperature so that muscles contract and relax more easily, nerve impulses travel more quickly

A VULNERABLE JOINT



The knee is the most complicated joint in the body and is used in all sports, which makes it highly vulnerable.

The **patella** can be dislocated by a very sharp twist. It can also be damaged by a direct blow. If one of the **quadriceps tendons** does not function properly, the patella may grate against the cartilage covering the knee joint.

The **patellar tendon** can be strained by overuse or from a sudden injury. It can also rupture under great force or if it is weakened by repeated strains.

A previous injury or internal damage can cause osteoarthritis in later life. The end surfaces of the **tibia** or the

femur – the **condyles** – wear away.

Abnormal twists or a sudden stress when the knee is bent can tear the **cartilages** between the femur and tibia.

If the foot slips while running, or if it is forced aside in a tackle, the knee may twist, straining the **medial ligament**. Powerful kicks or a fall sideways can also strain this ligament, as will overuse. The **lateral ligament** is injured if the knee is forced outwards when bent.

'Housemaid's knee' is a swelling of the **bursa** – the fluid-filled 'pouch' that protects the patella. Inflammation can be caused by repeated pressure or a sudden, forceful impact.

and synovial fluid flows more freely, making joint movement smoother. Cell metabolism in muscles becomes more efficient and so releases extra energy to work them. The overall effect is a more efficient athlete with a reduced risk of injury.

It is equally important to cool down (that is, reduce the activity slowly and stretch the body gently) after the sport. During heavy exercising, more blood is diverted to the working muscles. After the exercise, it takes a while to return to the heart. Light exercise helps it to get there more quickly and helps prevent nausea, dizziness and fainting.

Laser therapy

Sports injuries are treated by highly specialized means. Much research is constantly being done into the causes, prevention and cures. In addition to surgery, physiotherapy, massage and rest, one of the latest cures is the use of low-level laser therapy (LLLT).

LLLT is used on sprains, inflamed muscles, tendons and ligaments.

Even fracture recovery can be speeded up. Depending on the injury, the area is treated with laser energy penetrating to varying depths. The main advantages are fast healing and lack of side-effects.



Ultrasound can help reduce pain and heal inflamed tissue, especially around joints. Tiny bursts of high-frequency sound are applied with a probe.

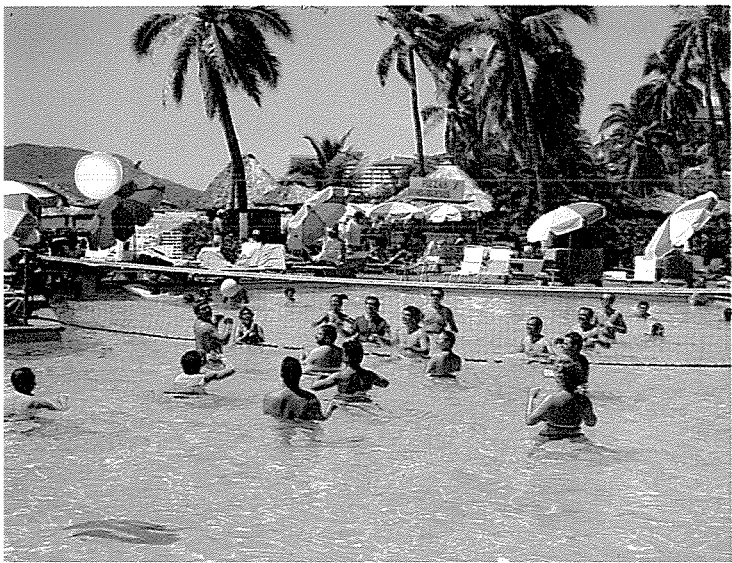
Just amazing!

OUT FOR THE COUNT

A PUNCH FROM FRANK BRUNO IS LIKE BEING HIT BY A 6 KG Mallet TRAVELLING AT 32 KMH. IT PACKS A FORCE OF 6320 NEWTONS – NINE TIMES THE FORCE OF GRAVITY.

Paul Raymond

HIGHS AND LOWS



SUMMERTIME BLUES

S.A.D IN WINTER

FUN IN THE SUN

DO YOU FEEL HAPPIER WHEN the Sun shines and depressed when the weather is grey and dull? Most people say they do. Do you work less well when it's too hot or too cold? People from cooler countries find it hard to work efficiently in the tropics without the benefit of air-conditioning.

In warm countries, hours of work are generally arranged so that workers can take a break, or even a siesta, during the hottest part of the day. Scientists are working to discover the links between the weather and human beings' moods and performance.

The long hot summer

It is generally believed that tempers grow shorter in hot, muggy weather. There is no doubt that 'crimes against the person' rise in the summer, when the weather is hotter, and fall in the winter, when the weather is colder. Research in the USA has shown a relationship between temperature and street riots. The frequency of riots rises dramatically as the weather gets warmer, hitting a peak around 27–30°C.

But is this effect really due to a mood change caused by the heat? Some scientists argue that trouble starts more often in hot weather merely because there are more people in the streets when the weather is good.

Psychologists have also studied how being cold affects performance. Researchers compared divers working in icy cold water at 5°C with others in water at 20°C (about swimming pool temperature). The colder water made the divers worse

Hormone levels – and hence our moods – may be affected by the weather. Gloomy weather can cause depression, but sunshine raises the spirits – as displayed by holidaymakers in a hotel pool in Mexico (top).

at simple arithmetic and other mental tasks. But significantly, their performance was impaired as soon as they were put into the cold water – before their bodies had time to cool down. This suggests that the low temperature did not slow down mental functioning directly, but the feeling of cold distracted the divers from their tasks.

Sunny dispositions

Psychologists have conducted studies showing that people become less sceptical and more optimistic when the weather is sunny. But this does not depend just on the temperature. An American psychologist studied customers in a temperature-controlled restaurant. They gave bigger tips when the Sun was shining and smaller tips when it wasn't, even though the temperature in the restaurant was the same.

A link between weather and mood is made believable by the

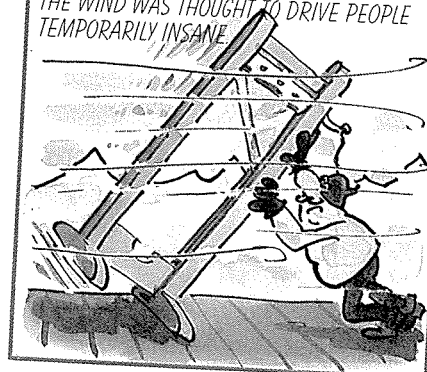
evidence for a connection between behaviour and the length of the daylight hours. This in turn might involve the level of a hormone called melatonin, produced in the pineal gland in the brain. The amount of melatonin falls with greater exposure to daylight. Research shows that melatonin plays an important part in the seasonal behaviour of certain animals.

For example, food consumption

Just amazing!

WIND OF PASSION

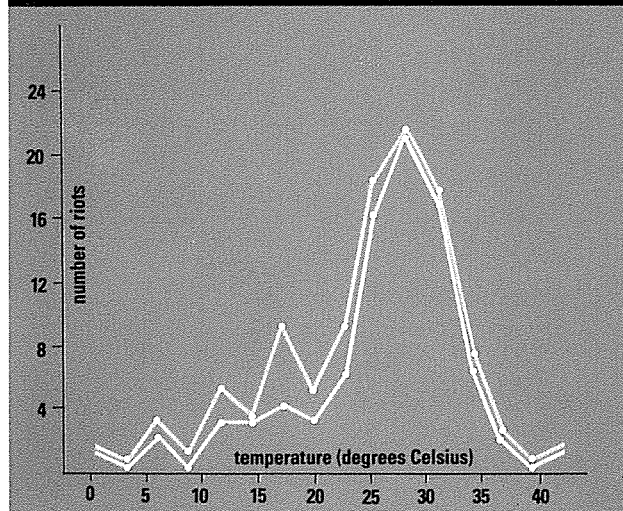
IN FRANCE, SERIOUS CRIMES COMMITTED WHEN THE MISTRAL WIND WAS BLOWING WERE ONCE EXEMPT FROM THE NORMAL SENTENCE – WHICH WAS DEATH – BECAUSE THE WIND WAS THOUGHT TO DRIVE PEOPLE TEMPORARILY INSANE.



Paul Raymond

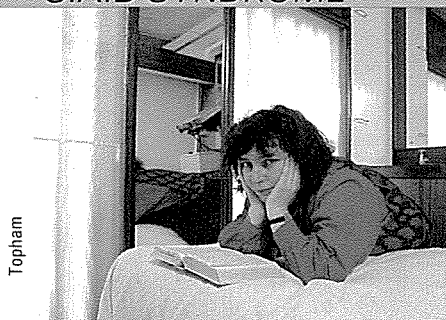


SUMMER IN THE CITY



City riots that swept the USA from 1967 to 1971 increased as the weather grew hotter (blue graph). When riots sparked by the murder of Martin Luther King are removed, the trend is even clearer (yellow graph).

S.A.D SYNDROME



The dull weather of winter drastically cuts down the amount of sunlight that we experience. Some people are strongly affected by this.

They become so depressed and lacking in energy that their work and social life are seriously affected. This condition has been given the name SAD (Seasonal Affective Disorder). Sufferers can fight back by making the most of any sunlight in winter and by spending a few hours each day under special, full-spectrum lamps. These provide more ultraviolet and blue-green light than ordinary fluorescent and tungsten lights. Some Russian scientists claim that children learn better after being exposed to ultraviolet light.

of stags increases during the winter, reaching a peak in February/March. It falls again to a low point in May, then rises to a peak in September, before dropping to another minimum in November. These changes seem to be triggered by varying melatonin levels.

In the laboratory, hamsters put on more weight when the nights are getting shorter and their melatonin levels are falling. On the other hand, if they are given injections of melatonin, they will stop eating altogether.

It seems that time cues provided by the changing lengths of day and night trigger changes in animals' behaviour — changes that are needed to cope with alterations in weather, and hence food supply, associated with the cycle of the seasons.

People's moods, too, have been shown to react to the length of the daylight hours. Sceptics might say that longer exposure to sunshine puts people in a better mood because they associate it with the happy feelings of holidays and freedom from responsibility.

The belief that rain and murky weather make people more unhappy is borne out by a study in Belgium, which showed that a telephone counselling service gets more telephone calls from people with suicidal feelings when it rains.

Warm feelings

Temperature can affect bodily functions, which in turn may well affect mood and behaviour. The warmer

the weather, the fewer children are conceived. A man's sperm count is at its highest when the average air temperature is a moderate 14–16°C and at its lowest at 23°C. Female fertility is also lower at higher temperatures. Perhaps because of this, the frequency of sexual intercourse is also lower at higher temperatures.

Positive ions

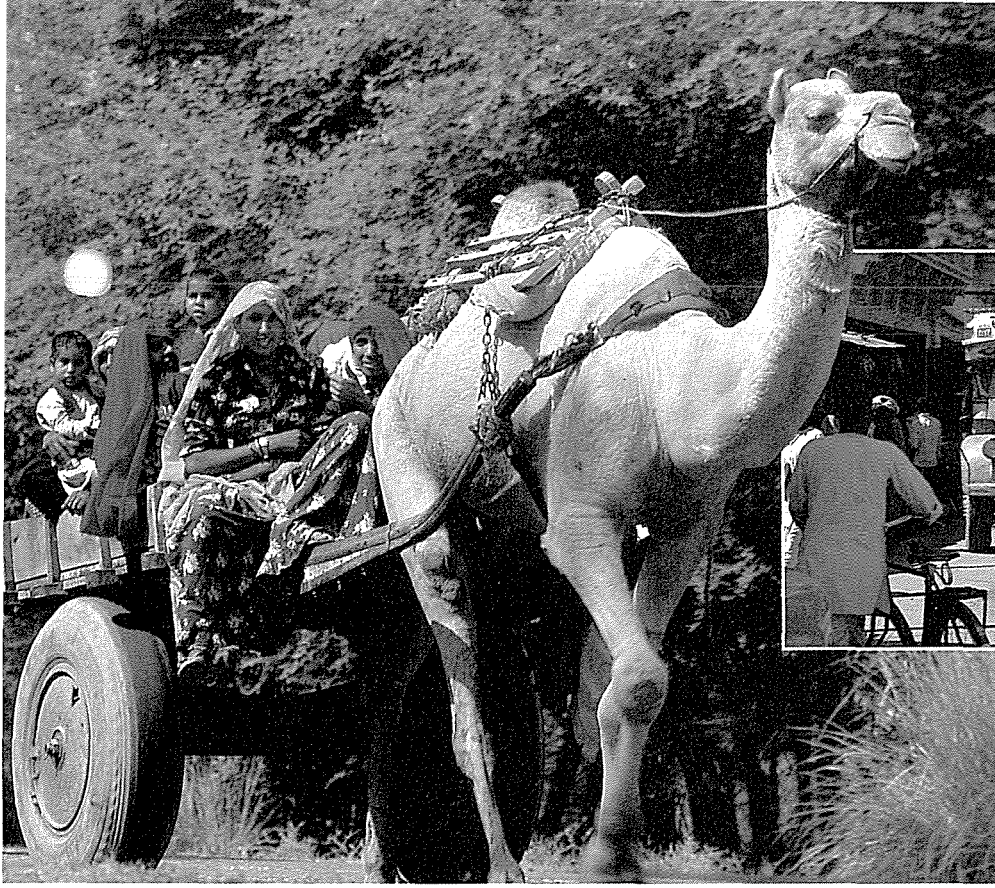
When there is a thunderstorm brewing, some people complain of the air being 'heavy' and of feeling irritable, moody and on edge. They may be reacting to the fact that the air can become slightly positively charged when large thunderclouds are generating the intense electrical fields that cause lightning flashes.

The positive charge increases the levels of serotonin (a chemical involved in sending signals in the nervous system). High levels of serotonin in certain areas of the nervous system make people more active and reactive and, possibly, more aggressive.

When certain winds are blowing, such as the Mistral in southern France and the Föhn in southern Germany, mood can be affected — and traffic accidents rise. It may be significant that the concentration of positively charged particles is greater than normal in these winds.

In the UK, 400,000 ionizers are sold every year. These small machines raise the number of negative ions in the air in a room. Many people claim they feel better in negatively charged air.





- ☉ FOUR LEG DRIVE
- ☉ HUMPING THE LOAD
- ☉ DRAUGHT ANIMALS



The camel and the bullock have yet to be overtaken by motorized transport in countries such as India. But although four feet are more economical than fossil fuel, both passenger and animal take advantage of modern technology for a smoother ride, with the aid of pneumatic tyres.

Tony Stone Photo Library, London

Hutchison Library

BRUTE STRENGTH

ANIMALS ARE STILL AN important source of motive power for most of the world's peoples. They carry people and goods, and draw vehicles and ploughs. Only slowly are they giving way to tractors, vans and motorbikes.

Motor vehicles are becoming ever cheaper and more convenient for people in the poorer countries. Tractors and small trucks can enormously increase the productivity and income of farmers and traders. However, animals are cheaper to buy and maintain. They do not need to be repaired with expensive spare parts that often have to be imported, and they reproduce themselves to increase their numbers.

☉ Under the yoke

The tasks that were performed in the West by horses, before the petrol engine took over, are carried out in India, China and other parts of Asia by the hump-backed zebu and its close relative, the water buffalo.

The buffalo's hump makes it easy to yoke the animal with a pole that passes in front of the hump and is

prevented from slipping sideways by vertical side-pieces. Since the horse lacks a hump, the first harnesses for horses had a breast-band, but this constricted the animal's windpipe when it tried to pull a heavy load. The use of the horse as a draught animal (that is, for pulling) became widespread in Europe only when the padded horse-collar was invented as late as the 10th century AD.

Owners of oxen and buffalo in Third World countries often take advantage of the arrival of motor vehicles. They shoe their beasts with cut-down car tyres and even equip their carts with car wheels and axles.

Oxen were almost as important in the West until quite recent times. The covered wagons of pioneers in America, Australia and South Africa were more often drawn by oxen than by horses. Oxen are still important in agriculture in many Mediterranean countries and in Eastern Europe.

In India and Burma, elephants have been domesticated for carrying goods and passengers. A large, mature elephant can carry a

load of as much as one third of a tonne. Elephants are also important in hauling logs in the dense forests.

Elephants were once used in warfare, both in Asia and in North Africa. One of them could carry a couple of soldiers and their weapons in what amounted to a tiny fortress.

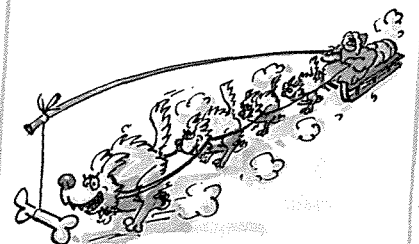
☉ Dune buddies

Perhaps the most impressive beasts of burden are camels. They are marvellously adapted to the dry regions in which they live. Ridden occasionally and also used for carrying goods, they may be used for hauling carts. A Bactrian (two-humped) camel can carry as much as 270 kg, while a dromedary (one-

Just amazing!

DOG GONE

IN 1987, SUSAN BUTCHER'S DOG TEAM SET A RECORD FOR THE IDITAROD TRAIL DOG SLED RACE IN ALASKA BY COVERING THE DISTANCE OF 1,688 KM - OR THE EQUIVALENT OF 40 MARATHON COURSES - IN 11 DAYS 2 HOURS AND 5 MINUTES.



Paul Raymond



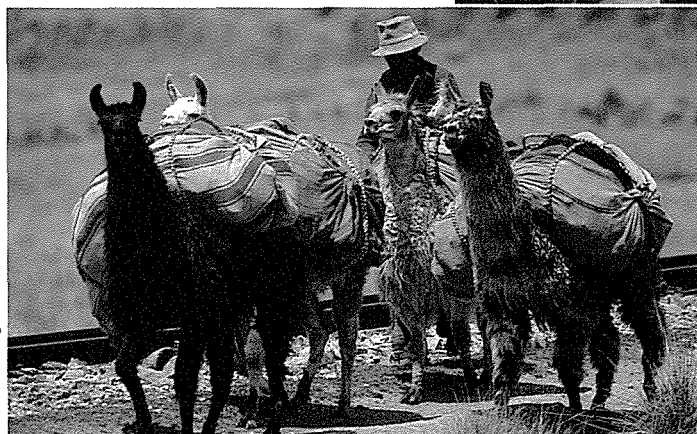
humped) can carry loads up to 405 kg. By comparison, a pack horse can carry about 125 kg. The dromedary lives in India, the Middle East and North Africa. It is longer-legged than its two-humped cousin, standing about 2 metres high at the shoulder. The dromedary has a lighter-coloured, shorter coat than the shaggy brown Bactrian, which lives in central Asia, northern China and Mongolia.

Handy in the Andes

The camels of today are descended from ancestors that flourished in North America millions of years ago. Other descendants of these extinct animals are the domesticated llamas and alpacas and the wild vicuñas and guanacos of the South American Andes. Llamas were used



Tony Stone Photo Library, London



Sullivan & Rogers/Bruce Coleman Ltd

Dallying llamas are goaded past railway tracks. Adapted to the high altitude of the Andes, they may make more reliable carriers than trains.

Bowed down under its load, a donkey carries empty soft drinks bottles in Morocco. Unlike a lorry that is usually used for this purpose, the donkey can negotiate the narrow streets without getting stuck.

as pack animals rather than for drawing vehicles, which were not used in the Andes before modern times. They can carry only about 45–60 kg.

Llamas are nimble and sure-footed. So too are sheep and goats, both of which are used for carrying

***Elephants** are the traditional beast of burden in Asia. Mature animals can carry loads up to a third of a tonne.*

light loads at great altitudes.

The donkey, or ass, was domesticated around 3000 BC in the Nile Valley, where it was used as a pack animal. Wild asses are creatures of arid regions, so their domesticated relatives need little food.

Farther to the east, in Central Asia, another type of wild donkey, called the onager, was domesticated by the Sumerians and used to pull their war chariots, until it was replaced by the stronger horse.

SHIPS OF THE DESERT

The camel's ability to journey across arid wastes without food or water, long after most other animals (including human beings) would have died, is legendary. Their bodies are adapted in many ways to the special needs of their desert homes, where food is scarce and oases few and far between.

Unlike other mammals, which sweat during the day to keep cool, camels conserve water by allowing their body temperature to rise throughout the day to as much as 11–14.5°C. They begin to sweat only when the external temperature rises above 40°C.

Their urine is very concentrated, which also helps to conserve water, and their thick coat helps to keep heat out during the day and in at night. The camel's body fat is not distributed around the body – this would hinder the loss of body heat during the day. Instead, it is concentrated in the hump, or humps, which are stores of energy. When camels go without food for a long time, their humps shrink as the fat is used up. If not working, they can last on this fat for up to ten months.

When a camel gets the chance to drink, it can consume over 100 litres of water – a quarter of its own body weight – at one time. Almost any other animal that did the same would die.



Tony Stone Worldwide



Nest building or weaving webs comes instinctively to animals. Weaver birds make nests of grass intertwined into a framework of knotted grass and twigs, which they hang from tree branches. Some species of spiders spin intricate webs from sticky thread (below) to catch prey.



Natural Science Photos

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NATURE'S

ARCHITECTS

- TAILOR-MADE HOMES
- NATURAL MATERIALS
- DEEP-SEA TUNNELS

BREATHTAKING HOMES – either short-lived nests in which to raise young, or long-lived 'cities' in which to shelter a community – are often built by animals. These structures are often complex and ingenious and, sometimes, massive in scale.

Often the function of a structure built by an animal is to provide a controlled environment. For example, the male three-spined stickleback digs a channel in the bed of a stream, then fills this up with scraps of vegetation. It bonds this together with a 'cement' it secretes, then burrows through the mass. The female lays her eggs in this tunnel. The tunnel not only makes it difficult for other fish to get at the eggs and eat them, it also allows the male stickleback to set up a stream of water over the eggs by fanning them with its fins and thus providing them with oxygen.

● Air conditioning

The elaborate hives of the social insects, such as honeybees, termites and many species of ants, provide a controlled climate as well as serving many other functions. The mounds built by termites in Africa and South America are made of mud and plant material bonded with saliva and excreta and can rise up several metres.

These mounds often have tall 'spires' that function as chimneys, creating up-currents of air through the nest. The air from the nest below rises up to the main chimney and, through it, to the side chim-

neys, whose walls are thinner. Through them, the carbon dioxide from inside is exchanged for oxygen from the outside. Thus, air circulates constantly, helping to keep the temperature, humidity and oxygen concentration at the correct levels. There is more carbon dioxide in the nest's atmosphere than in the air outside – enough to make a person lose consciousness if they had to breathe it.

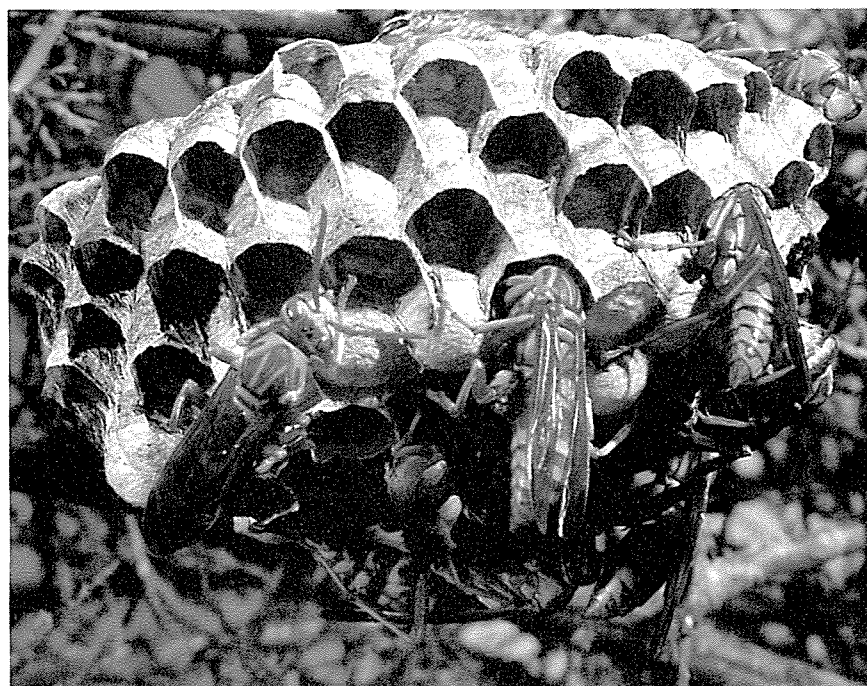
● Building materials

Animals use an enormous variety of materials in building. The paper

wasp uses, as its name implies, a paper-like material that it produces by chewing wood. Weaver ants 'sew' leaves together: the thread, silk-spun by the ant larva, is passed back and forth from leaf to leaf, gripped in the jaws of an adult ant.

Honey bees make their combs from wax that is formed in flakes on the underside of the worker bees' abdomens. Weaver birds build their

The honeycombed pattern of a wasp's nest is such a strong, yet light, structure that it is copied in the design of some aircraft wings.



Natural Science Photos



large, baglike nests by weaving together twigs and blades of grass. In some ants' nests, soldier ants will even plug holes in the walls with their oversized heads to keep out enemies.

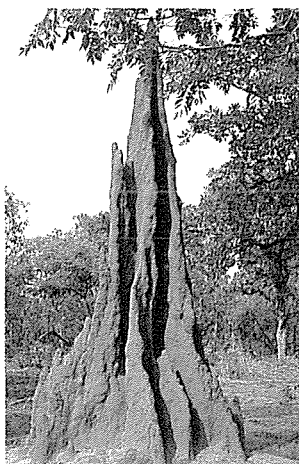
Dam-builders

Perhaps the most spectacular animal constructions are the dams and lodges built by beavers in North America. The beavers' long front teeth grow throughout the animals'

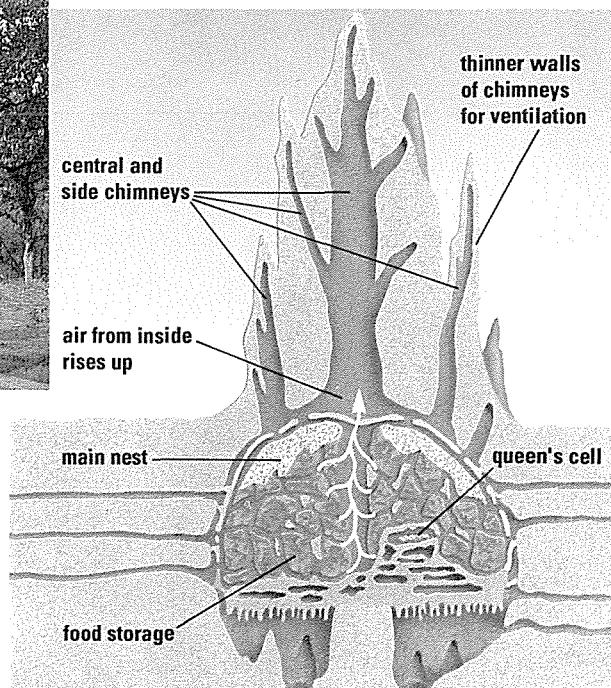


Peter Ward/Bruce Coleman Limited

Jen & Des Bartlett/Bruce Coleman Limited



Termite towers are made from mud mixed with the saliva of termites – a mixture that sets as hard as concrete. The tall chimneys provide ventilation for the main nest.



Chris Lyon

Beaver dams are constructed from twigs and stones to create an area of still water so the animals can gain entry to their burrows. With their huge incisors, beavers can fell trees up to one metre in diameter.



Natural Science Photos

lives and are kept to a manageable length by gnawing at the trunks and branches of trees. A beaver can fell a tree a metre thick. It eats the leaves and thin branches, then floats branches down the river to the site where the dam is to be built. The animal carries mud and stones in its forepaws and adds them to the branches to form the dam.

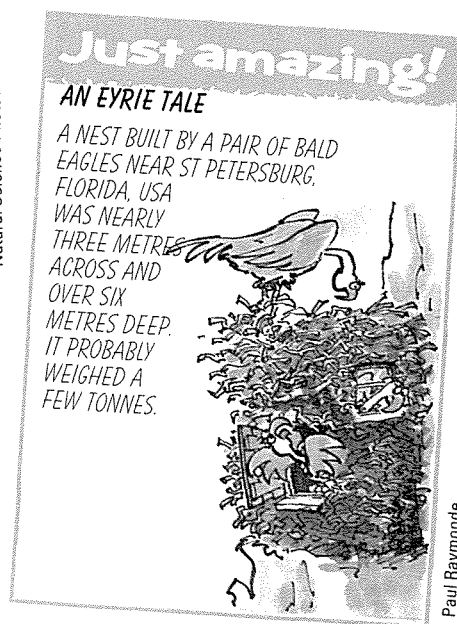
Some distance from the dam, in the lake thus formed, the beavers build a dome-shaped 'lodge' which

provides a haven for one or more family groups. The entrances are under water so that they give access to the water even when the surface is frozen over in winter. Beavers can strip the lake shore of all trees to a distance of hundreds of metres. When they have done this, they simply move on to a new site. Eventually, the old site silts up and new vegetation grows on the rich soil created by the beavers' building. In this way, the soil is

regenerated in a natural cycle.

Spiders build webs of sticky silk threads to trap small insects. There are many different types of webs, including the broad, flat 'orb' webs of garden spiders, the three-dimensional webs of cobweb spiders and funnel-shaped webs. Not many species of spider, however, make webs.

Half a dozen types of silk may be produced by the spider: one for making webs, one for wrapping prey, another for the sticky droplets on the webs, and so on. Silk is formed as a liquid in the spider's body. If it is to be used in building, it is solidified as it is squeezed out of the spider's body. The thread is highly elastic and immensely strong in relation to its thickness.



Paul Raymond





■ EMBRYONIC BRAIN

■ TWO HEMISPHERES

■ BRAIN SIZE

FOSSIL REMAINS SHOW THAT early Man had a much smaller brain than we have today. A close ancestor of modern Man known as Pithecanthropus had a brain weighing around 1 kg. Yet though it was smaller than our own, the brain of Pithecanthropus was bigger than the brain of a chimpanzee, which weighs around 0.4 kg.

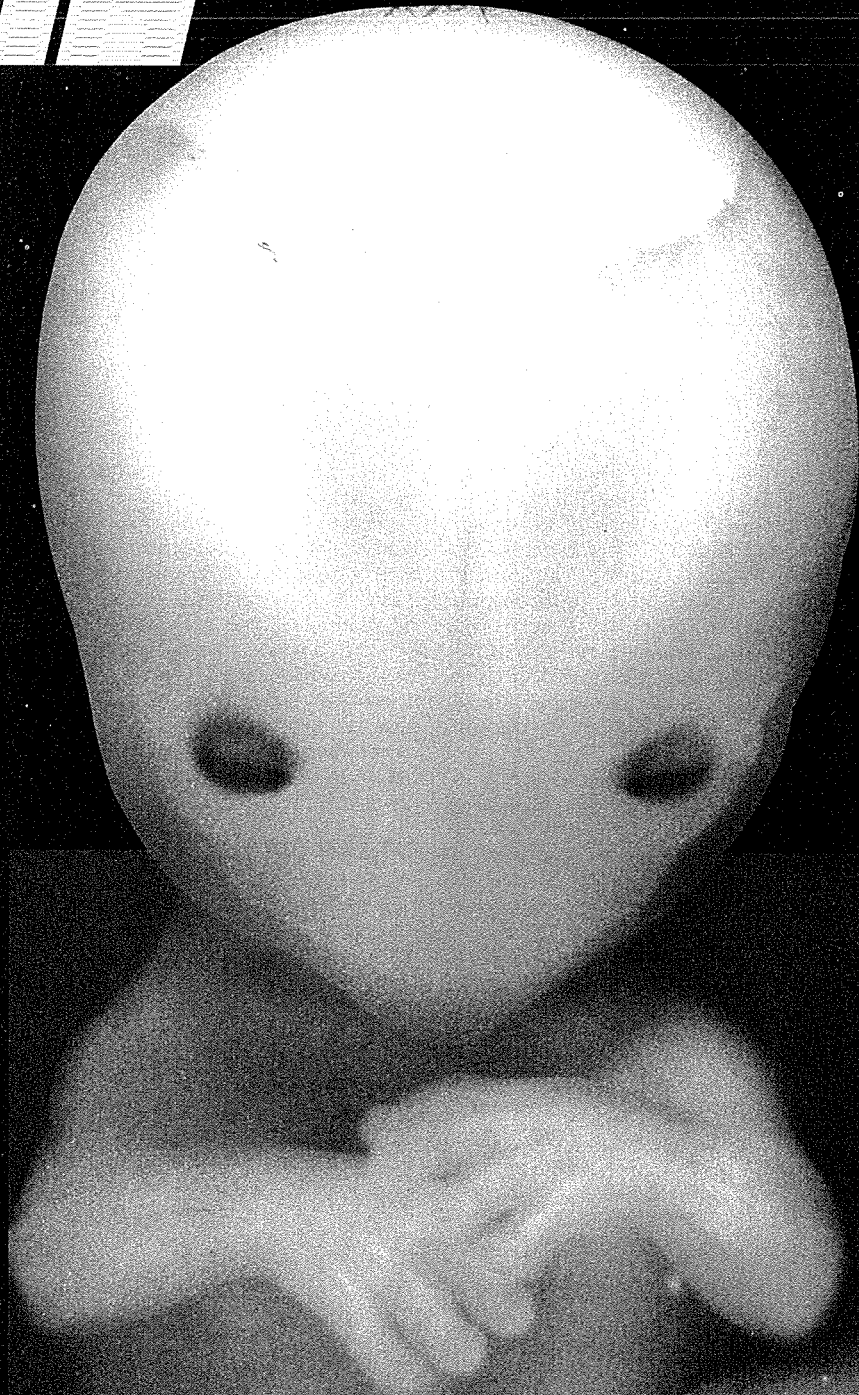
As Man evolved through a series of hominids like Pithecanthropus, the brain increased in size. The relative size of different parts of the brain also changed. Neanderthal man, who lived around 25,000 years ago had a brain about the same size as our own — 1.5 kg. However, the Neanderthal's brain seems to have been concentrated towards the rear of the skull. The brain of the modern human has a much higher proportion of front brain or forebrain, which makes us much better at intellectual and creative work than early Man.

The brain starts developing as soon as the human embryo develops, although at this early stage, brain cells are not noticeably different from other developing cells. Irreversible cell differences do not occur until about 20 days after conception. At this stage, various collections of cells start to specialize in the control of specific functions of the body.

● Taking shape

The most important of these collections or groups of cells is the hollow cylinder which forms the embryonic brain and spinal cord. As cell multiplication continues, the basic neurons or nerve cords take shape. A little later, the brainstem and spinal cord neurons begin to send out axons connecting the nerves to the muscles.

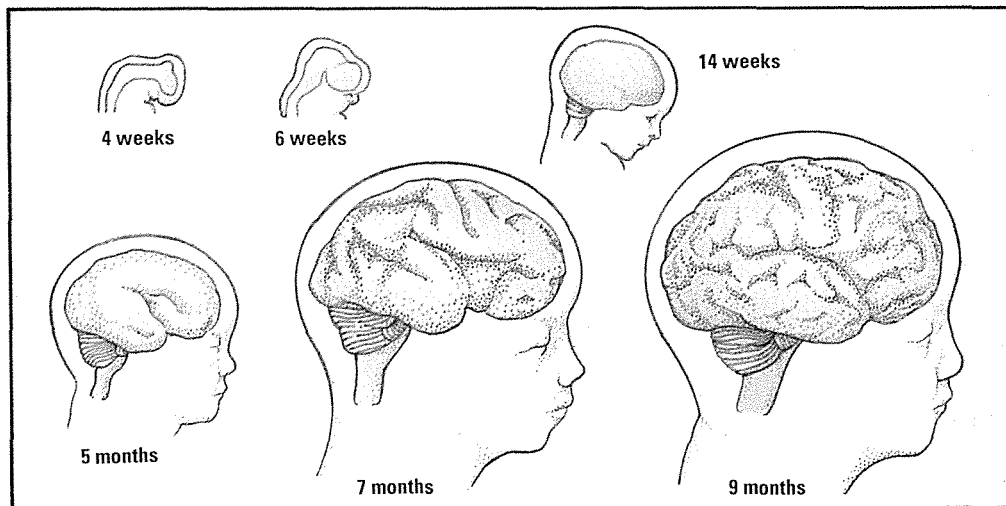
This process is swiftly followed by the growth of sensory cells, which begin to take in impressions from the world outside the embryo. By the end of the first eight weeks of embryonic life, the nervous system is quite well developed. The subsequent 32 weeks up to birth are taken up with more and more



At 12 weeks, bone has formed in the cranium to protect the brain. The head and brain are already further developed than the body.

Purkinje cells in the cerebellum (hindbrain) control balance and muscle movement. Branching neurons transmit messages from brain cells.





Three weeks after conception, the slab of cells that will form the brain and spinal cord rolls into a tube. By four weeks, the primitive divisions of the brain appear as swellings at the head end of the embryo.

Spina bifida is caused by a gap in the cylinder of bone around the spinal cord. It results in varying degrees of handicap – depending on the part of the back affected and severity of damage to nerves.

elaborate growth. By the time the baby is born, its brain is already a small version (approximately two-thirds the size) of the adult brain.

When the baby arrives in the outside world, the task of forming the inter-connections between brain cells begins. This process is not automatic – it only happens if the baby is stimulated by activities and contact with adults, which start it off on the learning process. Infancy and early childhood are the best times for a child to develop all kinds of mental processes and manual skills.

A well-known example of this learning process is in the teaching of languages. A child taught two, or even three languages by native speakers will grow up capable of speaking each of those languages with the correct accent.

Unfortunately, lack of stimulation during the early months and years of life can lead to quite marked

deficiencies in brain growth. Even worse, it appears that this lack of early brain development cannot be put right later in life.

The two hemispheres (halves) of the cerebrum – the back of the brain – control opposite sides of the body. This is illustrated by the way that people with brain injuries behave. If the damage occurs to the right side of the brain, the left side of the body is disabled and the other way round. It works like this because nerve impulses from one side of the brain cross over to the other side, before they leave the brain via a bridge of nerve fibres known as the corpus callosum.

The great divide

It has also been shown that the two halves of the brain are not identical either in the way that they are constructed, or in the work that they do. In most people, for example, the right side of the brain seems to be better at artistic, musical and



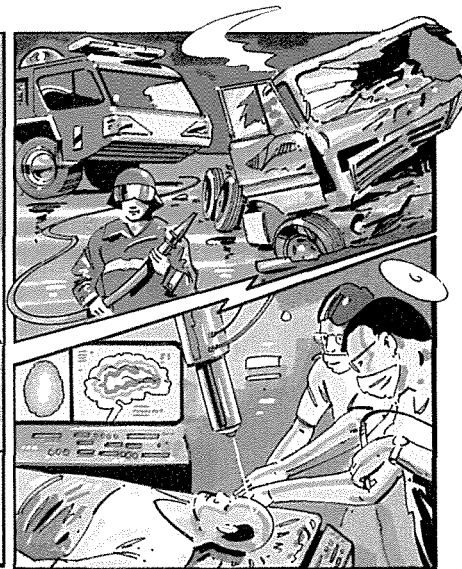
Camilla Jessel

creative activities, while the left-hand side of the brain is better at dealing with numbers, words, and problem solving.

Recent research has revealed that parts of the brain associated with speech are more developed in the left hand side of the brain as early as 24 weeks after conception. This

INTO THE FUTURE

TOWARDS THE SUPER BRAIN



▲ The cerebrum at the front of the brain (which deals with memory, consciousness and complicated thinking) will grow larger – so the forehead will also increase in size.

▲ Schools will run classes to encourage development of telepathic communication and telekinesis – the ability to move objects around by willpower and thought alone.

▲ Transplants of healthy brain tissue will be used to repair accident damage and disease. During operations, electrodes will be used to deaden pain.

indicates that the brain is already developing the ability to acquire a language.

It may be that late development of cells in this region during foetal brain growth can lead to the condition known as dyslexia. People who suffer from this condition can be perfectly intelligent, yet still have severe problems learning to recognize words. This makes it difficult for them to read and write.

Other parts of the brain appear to have the capacity to develop at different rates before birth. This varying rate of development leads to the variety of abilities and talents that is a characteristic of humans.

These differences in development are caused by instructions carried in the genes of each individual that

control the development of nervous tissue. External factors also influence the development of the embryo brain because it is very susceptible to influences reaching it through the mother.

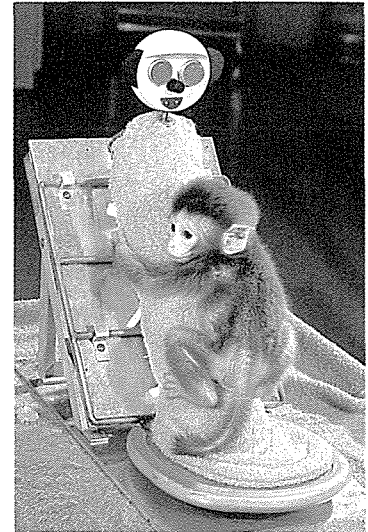
Some external factors are under the direct control of the mother; for example, she can decide whether or not to smoke and/or drink alcohol during her pregnancy. Failure to eat a healthy diet may also affect brain development owing to a lack of nutrients. A similar lack of the right nutrients occurs, because of an addiction to the wrong sorts of food, but in many parts of the world it is due to poverty.

Unfortunately, certain viral infections, such as German Measles (Rubella), can also cross the

STUNTED GROWTH

Experiments conducted on rhesus monkeys have shown that in infants brought up in complete isolation, the thalamus – the part of the brain that registers pleasant emotions – is abnormally small.

If, however, the young monkey is given an artificial 'mother' covered in a soft, furry cloth to which it could cling for comfort, then the thalamus develops normally.



Martin Rogers/Colorific!

BRAINY CREATURES

Dolphins, porpoises and some whales are believed to be the brainiest of our fellow creatures. These mammals all have quite large, complex brains and intelligent behaviour patterns. Research reveals that such marine mammals make a large number of complicated whistling sounds that appear to be comparable with human communication using speech. They can also learn to identify objects and to tell the difference between them fairly easily.

Dolphins learn particularly quickly and have already been used to retrieve objects from the sea bed. They also appear to enjoy contact with humans, whether they are offered food or not. An exciting hope for the future is that we may be able to learn the dolphin 'language' and so break through the communication barrier between humans and animals.



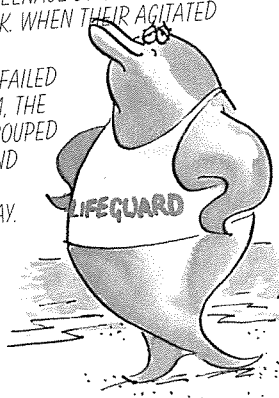
George Bingham/Bruce Coleman Ltd

mother is Rhesus negative, in a second pregnancy and with a Rhesus positive foetus, her blood could form antibodies that would attack the baby's red blood cells. This could cause the child to be still-born, or to die at birth due to severe anemia.

Just amazing!

ON THE LOOK OUT

IN 1989, DOLPHINS TRIED TO WARN AN AUSTRALIAN TEENAGE SURFER OF A SHARK ATTACK. WHEN THEIR AGITATED CALLS AND MOVEMENTS FAILED TO ALERT HIM, THE DOLPHINS GROUPED TOGETHER AND CHASED THE SHARKS AWAY.

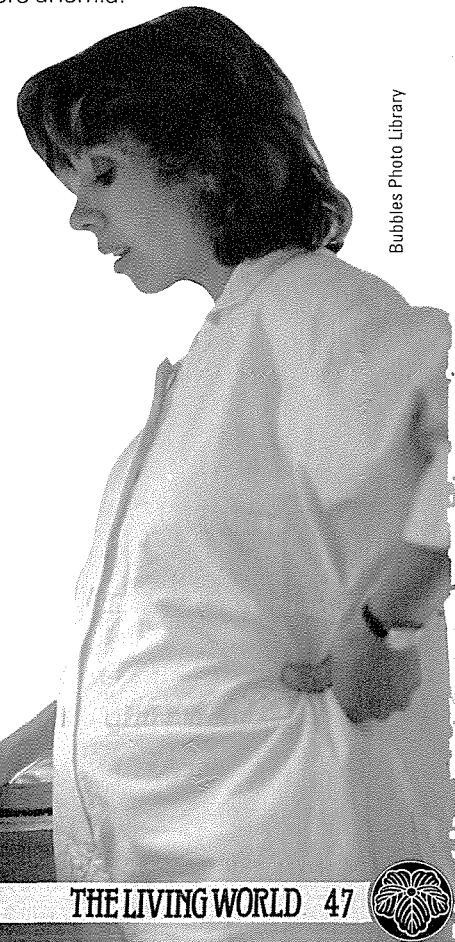


Paul Raymond

placenta. If this happens early in pregnancy, there is a possibility of mental retardation because the virus causes changes in the fluid that surrounds the brain.

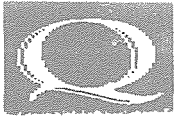
It is recommended that women who intend to have children are immunized against Rubella. Pregnant mothers normally have a blood test to check their blood type. If a

Alcohol can pass from the mother's bloodstream into the baby's because its molecules are small enough to get through the membrane separating the two. Once in the foetal bloodstream, it can impair growth, including brain development.

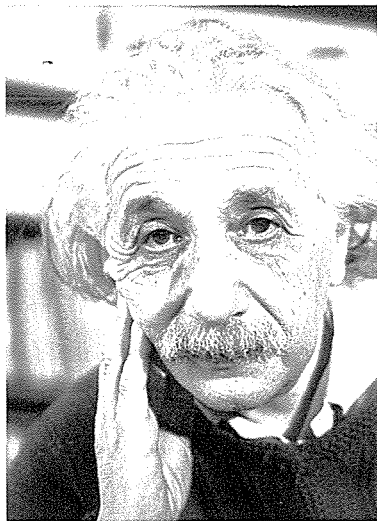


Bubbles Photo Library



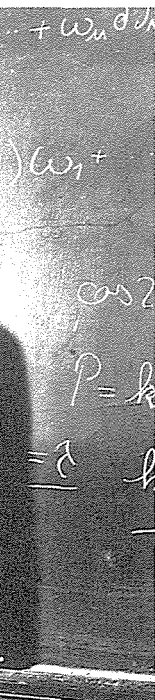


Albert Einstein 1879-1955, physicist. Einstein was a German physicist famous for his Theory of Relativity. This laid the foundations of present-day ideas of how the Universe was formed.

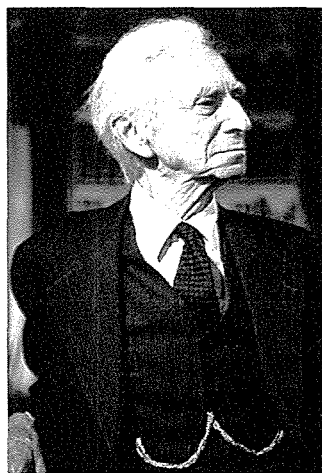


Popperfoto

Neils Bohr 1885-1962. A Danish physicist, Bohr investigated the way atoms behave and the energy they contain. During World War II he worked in America on the atomic bomb project.



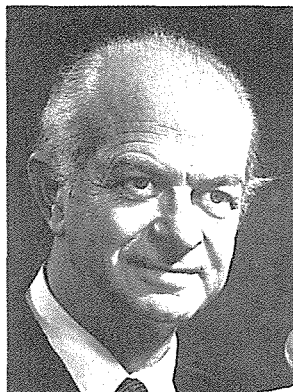
AIP Neils Bohr Library



Rex Features

Bertrand Russell 1872-1970, philosopher. Originally a mathematician, Russell's work led him into philosophy. His book *The History of Western Philosophy* is a standard work. He strongly opposed the use of atomic weapons.

Linus Pauling born 1901, chemist. Pauling was the second person to win two Nobel Prizes. His first was for Chemistry (molecular bonds) in 1954; his second for Peace (banning atmospheric atomic tests) in 1962.



Noam Chomsky born 1928, linguistic philosopher. Chomsky made important discoveries about how people communicate using language. He believes there is a basic mental capacity for language deep in the human brain that unites all races.

Popperfoto

Alan Turing 1912-1954, computer architect. Turing (far right) was responsible for the basic design of the electronic computer. His original machines were based on valves, not transistors, so they were large and slow.



Jean Piaget 1896-1980, psychologist. Piaget was the Swiss founder of the science of developmental psychology. His ideas on the learning process in children have influenced countless teachers.



Yves de Brahe/Black Star/Colorific

Stephen Hawking born 1942, physicist. With his best selling book *A Brief History of Time*, Hawking became a scientific 'super-star'. The book deals with the birth and death of the Universe in accordance with the laws of physics.

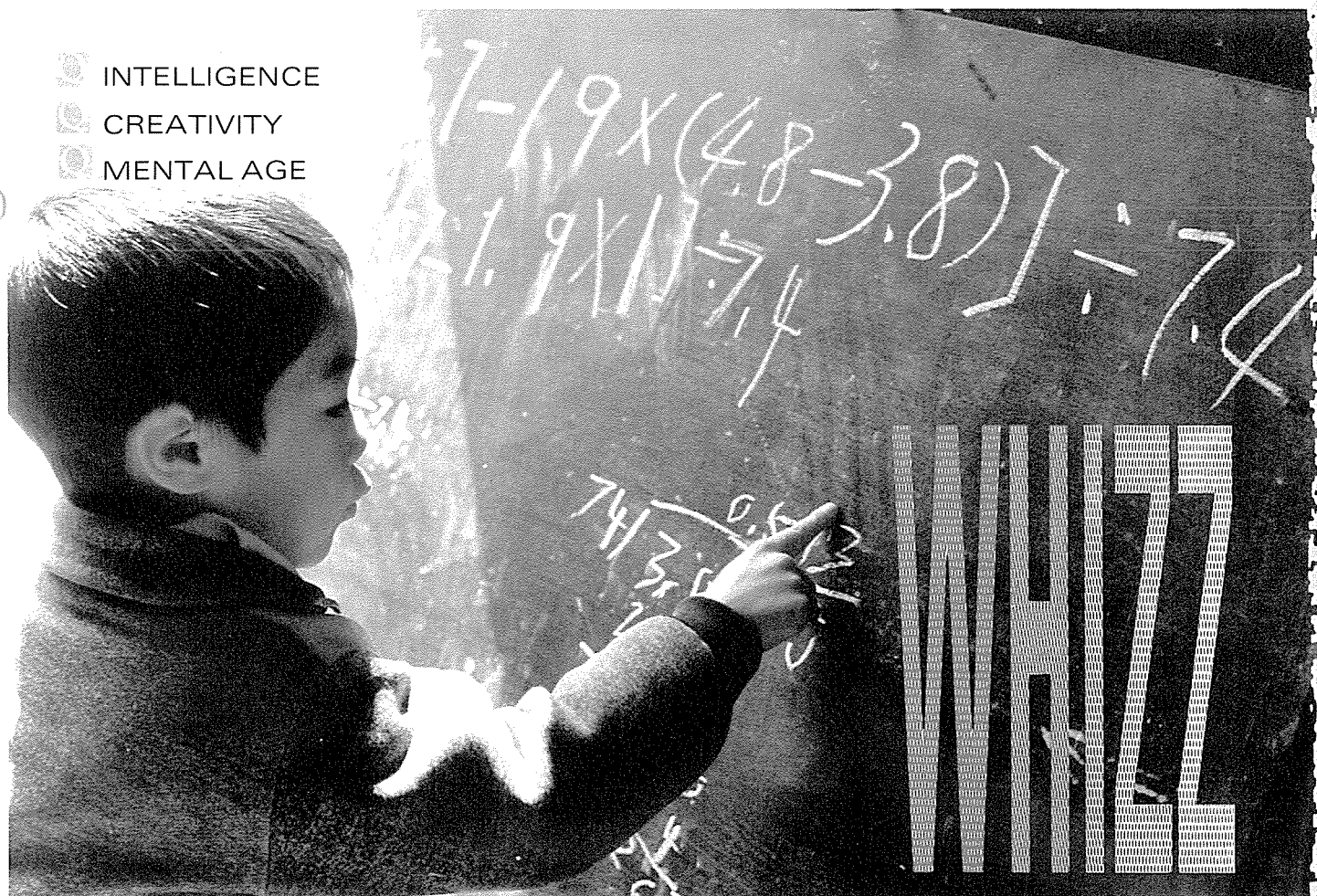
Manni Mason's Pictures
National Archive, History of Computing, Manchester Univ.

Popperfoto



- INTELLIGENCE
- CREATIVITY
- MENTAL AGE

Gamma/Frank Spooner Pictures



EVEN THE MOST INTELLIGENT people in the world cannot agree on what intelligence is. Everybody knows roughly what it is, but it is hard to define precisely – and even harder to measure.

Over the years, some psychologists have called intelligence 'the ability to learn'. Others have called it 'the ability to adapt adequately to the environment'. Still others have thought it 'a general tendency towards achievement'.

Types of intelligence

In 1971, psychologist R. B. Cattell suggested that there were two types of intelligence, which he called crystallized and fluid. A child with crystallized intelligence would accurately produce a straightforward answer to a problem, but not attempt to go beyond it. However, a child with fluid intelligence could somehow side-step the expected answer to a problem and produce a creative and unexpected answer.

The author and creative thinker, Edward De Bono has described what happened when some children were asked to solve the problem of how to build houses faster. Most of their drawings showed more highly mechanized versions of nor-

A four-year old prodigy demonstrates his remarkable abilities in performing mathematical calculations.

mal building methods. But one extremely creative child suggested starting with a huge balloon that had an attractive wallpaper pattern printed all over the inside. After inflating the balloon and spraying it with concrete, cut-outs would be made for windows and doors.

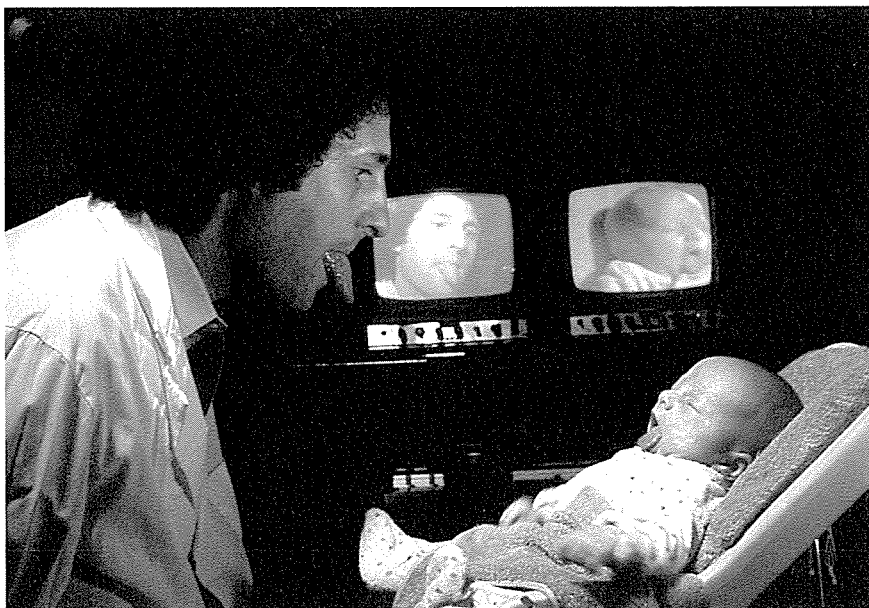
The French psychologist Alfred Binet devised a series of problems

for testing children's intelligence. Binet reasoned that, if the average six-year-old could copy a drawing of a square, but the average five-year-old could not, then this test was a suitable measure of six-year-old intelligence.

From the results of Binet's work developed the concept of mental age. He supposed that a child's

KIDS

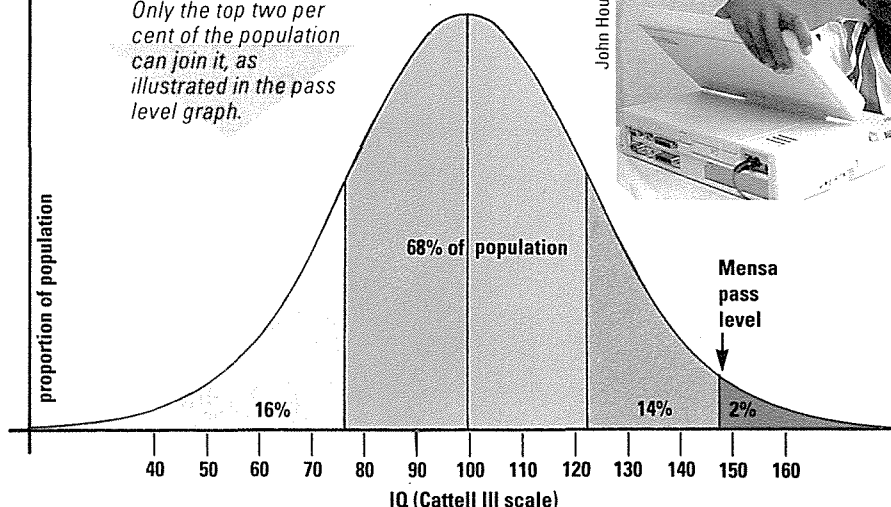
Babies soon learn to copy human behaviour. Some can be taught to speak several words within nine months.



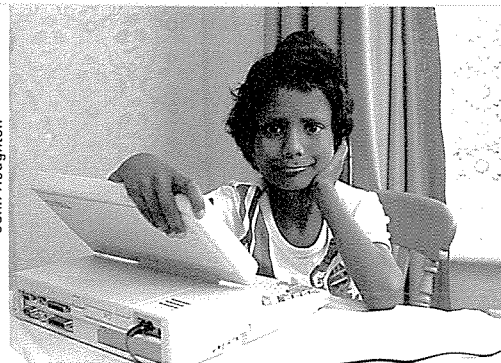
Enrico Ferorelli/Colorifici



Mensa is a society for people with a high IQ. Only the top two per cent of the population can join it, as illustrated in the pass level graph.



John Houghton



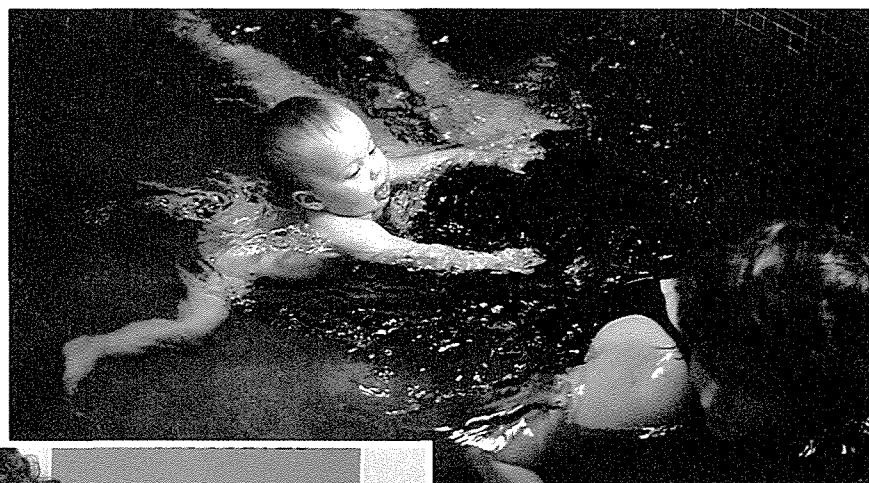
The youngest child to pass GCE A-level in mathematics was Ganesh Sittampalam, who was 9 years and 4 months old when he took the exam. At 13, he gained a mathematics degree.

tages. Some children who perform poorly in verbal tests can score well in the non-verbal sections.

Conventional tests are useful in assessing a child's potential for future academic work. But they are virtually useless in measuring perseverance or creativity — both important aspects of other types of work and, indeed, of a versatile human being.

brain increased in intellectual power year by year. So two children, shown by the tests to have the same intellectual power, had the same mental age — regardless of their actual ages. A 13-year-old whose results matched those of the average 12-year-old was said to be one year retarded, while a 13-year-old whose results matched those of the average 14-year-old was said to be one year advanced.

A person's intellectual capacity, does not go on increasing indefinitely. Somewhere between the ages of 14 and 18, it begins to level



Institute for the Achievement of Human Potential, Philadelphia



Gamma/Frank Spooner Pictures

Young children can be trained to develop a wide range of skills, including learning from books and swimming (inset above). While some claim that training improves children's intelligence, others believe the children are simply more able to demonstrate their intelligence rather than responding to training.

out until there is no yearly improvement at all. One year's 'backwardness' at the age of, say, five is far more significant than at the age of 13, since it represents a much greater proportion of the child's life.

Testing IQ

It was later suggested that the ratio of mental age divided by true age was a better measure than the difference between them. This ratio, when multiplied by 100, is called the intelligence quotient, or IQ. A child whose mental and true ages are the same is, by definition, an average child and has an IQ of 100.

Testing by this method has shown marked differences between people of different backgrounds — for example, wealthy and deprived people in the same country. This is one reason why many psychologists do not regard such traditional tests as adequate.

Children from homes where books, toys, records, lively conversation and other stimuli are present often perform better in school discussions. Since most tests are based on a child's skill with words, it is difficult to measure accurately the intelligence of children whose homes do not provide such advan-



Sally & Richard Greenhill

Mozart and Mendelssohn, both child prodigies, have inspired many parents to try to develop similar talents in their own children.



TRADING ON THE FUTURE



Coffee beans are picked in vast amounts in South America for consumption – and trading – around the world. Coffee is traded on the FOX (Futures Options Exchange) floor by open outcry. Prices are monitored and reported back to clients by the brokers or their representatives (inset above). Coffee options are traded in contracts of 5 tonnes each.



International Coffee Organization

TAKING RISKS

PROFIT AND LOSS

METAL FORTUNES

GROUPS OF PEOPLE YELLING at each other is standard procedure for setting the price of many goods in daily use – commodity futures trading is what the professionals call it.

Commodities are bought and sold in many markets around the world. In London, for instance, there is the London Metal Exchange, which deals in 'hard' commodities – metals such as copper, lead, zinc and nickel. The London FOX (Futures and Options Exchange) deals in 'soft' commodities such as sugar, coffee, cocoa and rubber.

Two of the world's leading commodities exchanges are in Chicago, operated by the Chicago Board of Trade and the Chicago Mercantile Exchange. There are also important commodity exchanges in New York City.

These American exchanges deal in all sorts of hard and soft commodities, including heating oil, live cattle and hogs, pork bellies – and even orange juice.

Trading sessions in commodity exchanges can be lively affairs. The

traders in a particular commodity gather in a ring, known as a pit, and shout out whether they are buying or selling, and what their prices and delivery dates are. The deals they make in this 'open outcry' trading are later confirmed by written contract.

Making money

But this style of trading may soon vanish, as electronic trading systems are introduced. The Chicago Mercantile Exchange, for example, has developed a computerized trading system, called Globex, which has operated a 24-hours-a-day world-wide service since June 1992.

Commodity futures trading is a way for merchants to protect them-

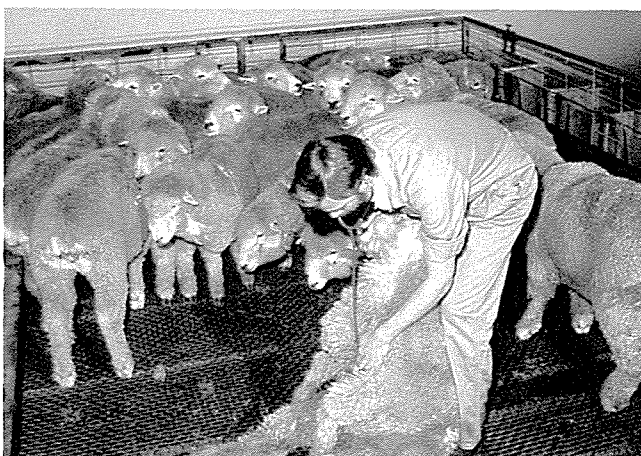
selves from unexpected rises in the cost of the goods they need and for producers of goods to protect themselves from falling prices. But trading on the futures market is a gamble.

The key to futures trading in a commodity lies in the difference between the spot price and the forward price. The spot price is the cost of goods available for immediate delivery; the forward price is the price you pay now for goods that are yet to be delivered.

Hedging your bets

Suppose you were a miller, making flour from wheat. In order to compete with your rivals, you would need to buy your wheat as cheaply as they did – if not cheaper.

Live sheep are examined by a vet before they are exported from Australia. There is a world-wide market in meat, dealing mostly in frozen carcasses. However, Muslim countries that need to import meat prefer to buy live animals so that they can slaughter them according to their own religious customs.



Australian Overseas Information Service, London





One way to protect yourself against price rises would be to buy some of your wheat – before you actually needed it – on the futures market. For instance, one spring you might hear that the American wheat harvest due later in the year was likely to be low, causing a rise in world wheat prices. So you could buy wheat, to be delivered in September, at a forward price of, say, £100 a tonne.

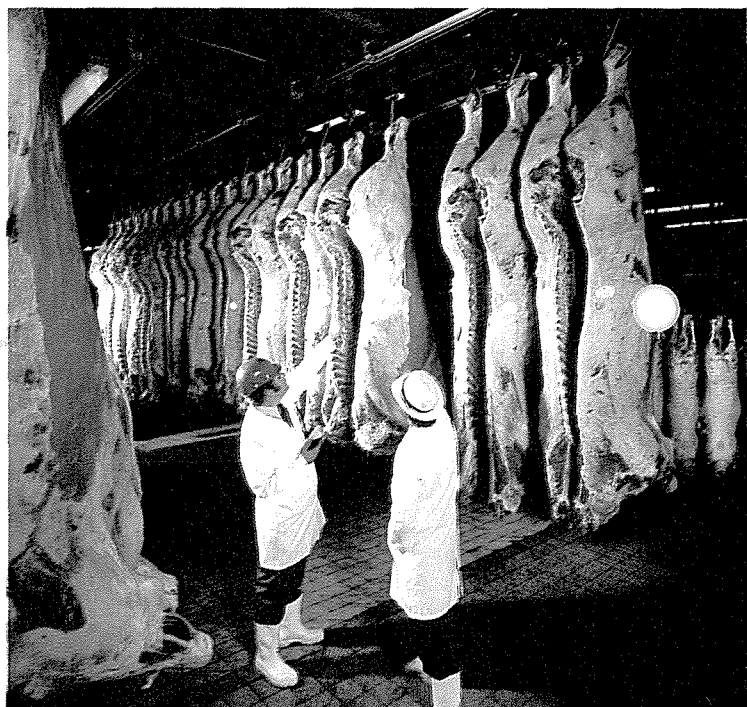
If the American wheat harvest that year did turn out to be low, the spot price in September might have gone up to £125 a tonne. But because you had bought at £100, you'd have saved £25 a tonne on your September wheat. This process of guarding against price rises by buying on the futures market is called hedging.

Because of the possible differences between spot and forward prices, there is big money to be

Tea is big business – 1,355 cups are drunk per person each year in Britain. Tea is a 'physical commodity'; that is, it is bought and sold, but not traded on the futures market as yet.

Meat can be bought and sold – several times over – on the futures market, without buyer or seller ever seeing it.

A golden harvest of wheat spells good fortune for the farmer, but he can hedge his bets against a poor crop by speculating on the futures prices.



Meat and Livestock Commission

Just amazing!

DROOPING PRICES

FUTURES MARKETS GO A LONG WAY BACK IN HISTORY. SPECULATION IN TULIP BULB FUTURES SPARKED A STOCK MARKET CRASH IN AMSTERDAM IN THE 17TH CENTURY.



Paul Raymond



Ivaldi/Jerrican

made by people prepared to risk buying futures: if prices rise, they can sell at a profit.

Speculating

If you were a speculator buying September wheat in spring at £100 a tonne, then selling it in September at £125 a tonne, you would be making a profit of £25 a tonne (less commission). You would not even have to take delivery of the order. Of course, if the spot price of wheat in September turned out to be only £90 a tonne, you would lose £10 a tonne, plus any commission paid on the deal.

Futures contracts can also be bought and sold many times before the goods are due for delivery. Their prices can both rise and fall before that date.

OPEN YOUR EYES AND LET IN light. The energy that enters activates an extremely sensitive and complicated system – a system that enables us to perceive the world around us visually.

The eye acts somewhat like a television camera. It has a lens at the front that can focus the light from near or distant objects by changing its shape: the fatter the lens, the closer the object; the thinner the lens, the further the object.

The iris controls the amount of light entering it by dilating or contracting, rather like the lens in a camera. The aim is to get the image of the outside world in focus and at the right level of brightness on the area at the back of the eye called the retina.

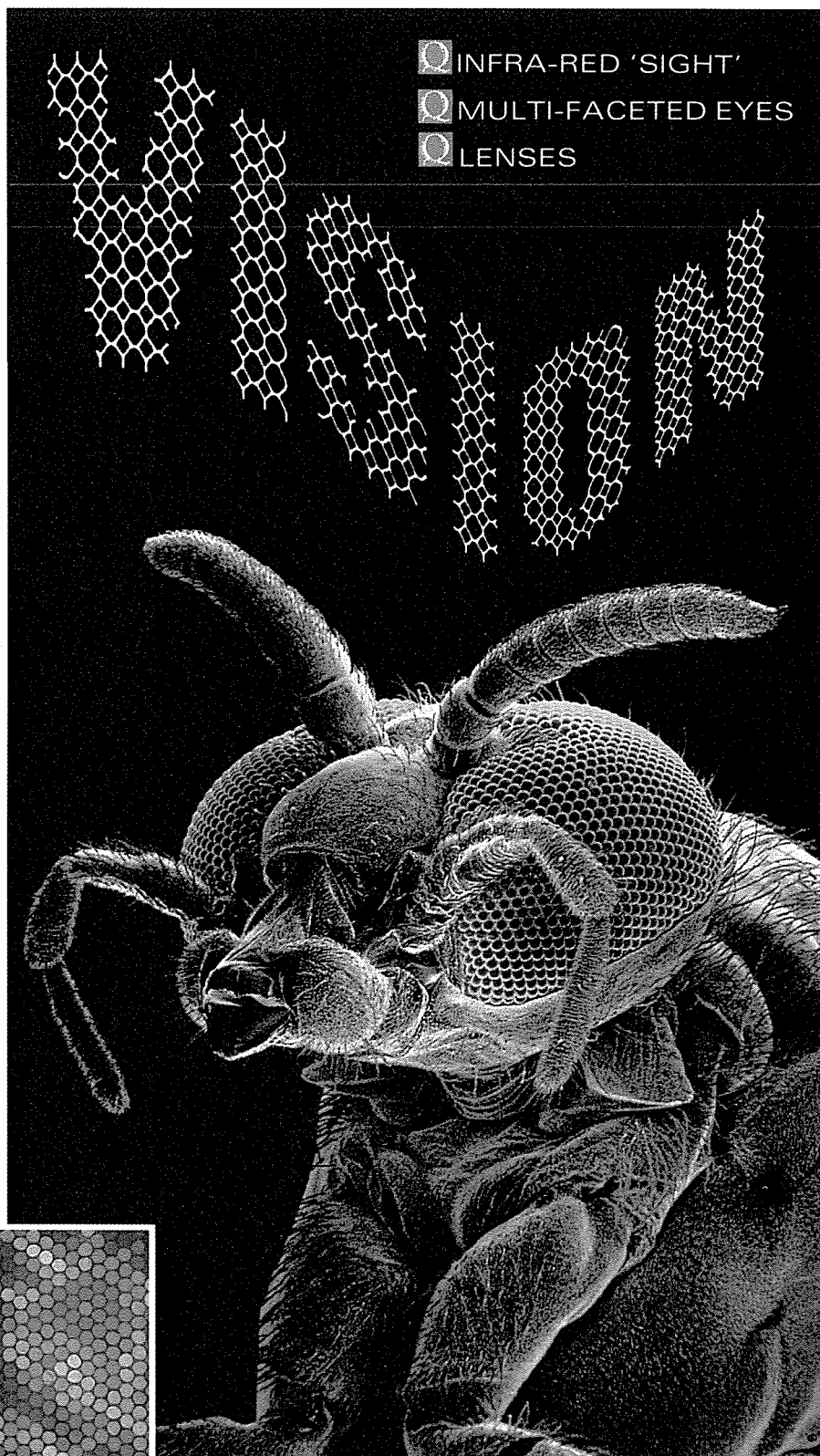
Rods and cones

There are about 125 million tiny light sensitive cells on the retina. Many of these cells can detect the energy carried by just a photon or two of light. There are two types of light sensitive cell: rod cells and cone cells.

Rod cells are very sensitive to dim light and give us black and white vision, while cone cells respond to brighter light and give us our colour vision. Go outside on a dark night and things look like a black and white film on TV – this is because only the rod cells are sensitive enough to pick up the low light levels around.

Rod cells are spread relatively evenly over the retina while cone cells are concentrated in an area called the fovea. This is a tiny area about 1 mm across where our attention is focused. You have to bring an object into focus at the fovea to see it best.

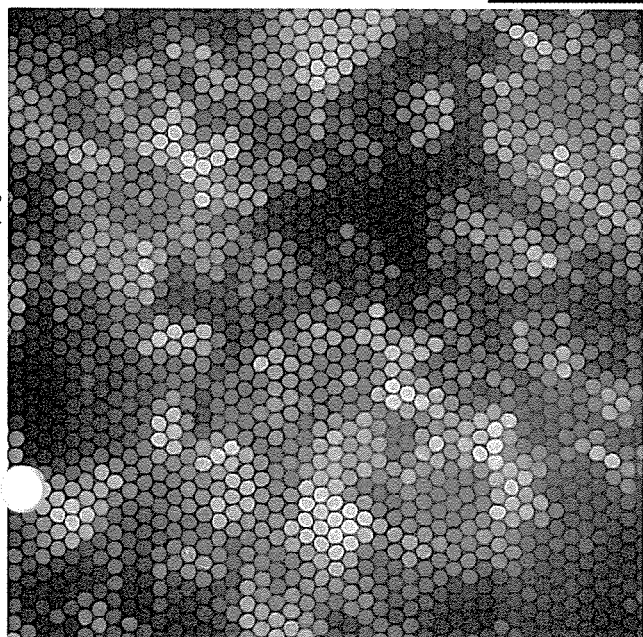
When you read a page you only really properly see a word or so at a



Many eyes make light work. The many faceted eye of insects (such as the fly's, above) consists of several hexagonal units. Each contains a lens that reflects light on to light sensitive cells. The fly's eye view of flowers would appear in a hexagonal grid (left).

time. Look at a single word on this page without moving your eyes for a few seconds and you'll see how hard it is to make out any others very far away from it. Most colour perception also takes place at the fovea.

Both rod and cone cells contain pigments that respond to the energy in light by generating a minute electric current. Rod cells are sensitive to light across the visible spectrum, while scientists think that there are different cone cells sensi-



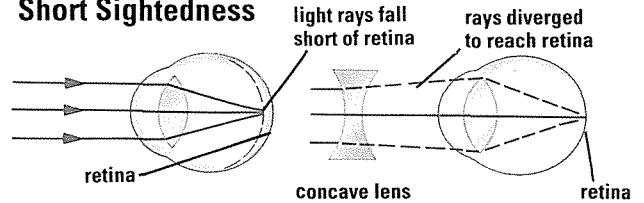


An eagle's eye view is wide – and detailed. An indented area on the retina magnifies the centre area, allowing the eagle to distinguish prey that is camouflaged.

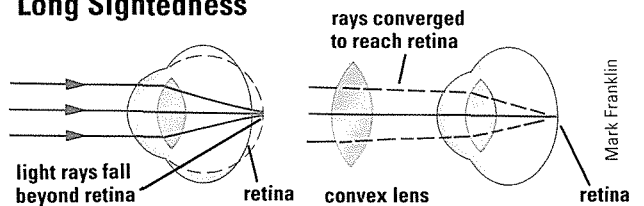
Animal eyes vary greatly in appearance, structure and in how much fine detail they can see. But the essential mechanism of sight – electromagnetic energy hitting a light sensitive cell, causing it to fire and send a signal to the nervous system or brain – is similar to the human experience of sight.

However, eyes in different crea-

Short Sightedness



Long Sightedness

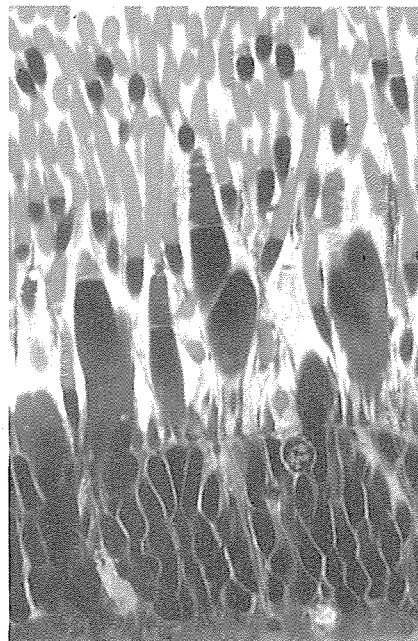


John Downer
tive to each of the three primary colours: red, green and blue. Effectively, the complete range of colours we see can be made by mixing lights of these three colours.

The tiny current thus generated makes both rod and cone cells send a pulse down a nerve towards the brain. Each cell is capable of sending approximately 1,000 such pulses a second. Even a fantastic supercomputer like the brain would have trouble making sense of 125 million cells each sending it signals 1,000 times a second.

Fortunately, the cells do not fire constantly at this rate and, on the way to the brain and in the brain itself, the signals are interpreted by other cells. The first stage of this

Short sightedness can be corrected with concave lenses; long sightedness with convex lenses.



Light sensitive cells on the retina show up as rods (thin) and cones (purple bulbs). Below them lies a dense pigment layer.



The retina, the innermost coat of the eye, is an extension of the optic nerve and consists mainly of nervous tissue. Veins and arteries leave and enter via the optic disc (the yellow area).

transmission is at the retina where cells, called bipolar cells, collect pulses from groups of cells before sending information down the optic nerve towards the brain. There are about 800,000 nerve fibres leaving each eye.

The process through which we understand the messages that reach our brain is not fully understood. It is known that there are some cells that respond to movements and shapes, and others that compare input over time while looking for changes.

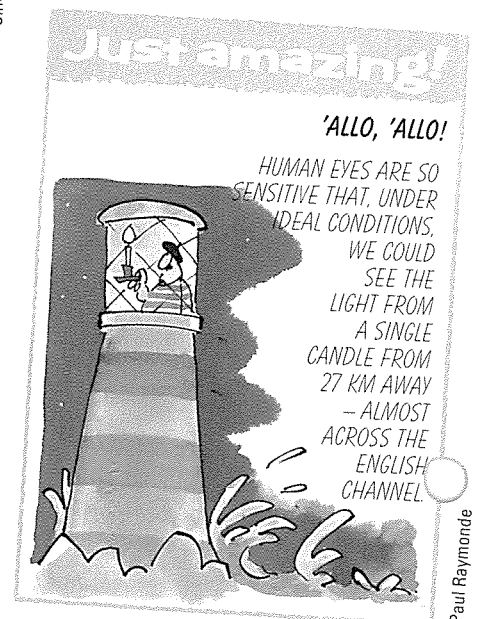
The amount of information is

whittled down as it travels further through the paths in the brain. Cells take input from groups of other cells via the nerve fibres. Groups of these, in turn, feed information to fewer cells as the brain makes constant comparisons and interpretations while responding to the input. Eventually, information about the outside world is perceived and becomes part of the constant flow of impressions, feelings and thoughts that make up our conscious minds. So much so, in fact, that we are rarely conscious of seeing at all.

tures are very diverse. They range from the human eye – with colour vision and great sharpness – to the light sensitive cells on the surface of an earthworm's head, where there is no lens as such – just a patch of cells that tell the creature where light is coming from.

Insects' eyes

Vertebrates have eyes with lenses that focus images on to their light sensitive cells just as in human eyes. But insects have eyes made up of many thousands of lenses, each of which aims light at only a few light sensitive cells. Such eyes are called compound eyes, but they are much less acute than eyes with single lenses. The bee has a compound eye with 15,000 of these lenses or facets. However, bees can detect movement in front of them,



Alexander Tsiraras/SPL

Sinclair Stammers/SPL

Paul Raymond



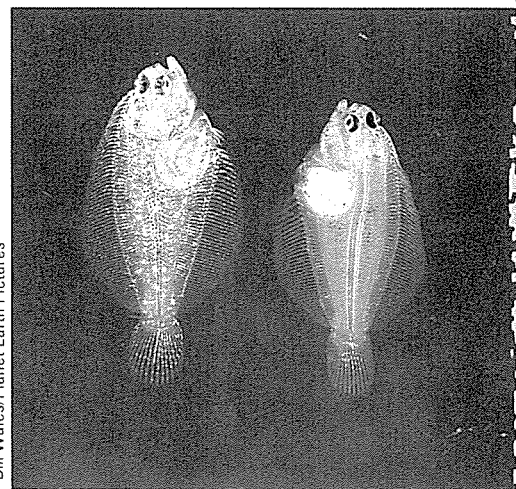
VISION

Gotcha! The snake uses small, heat-sensitive pads on its face to locate its prey. These can 'see' infra-red radiation from its victim's body heat (inset right) even in the dark.



John Downer

Shifty eyes. Newly hatched flat fish are born with eyes on either side of their face. As they get older, they take to the bottom of the sea bed and one eye migrates to join the other!



Bill Wales/Planet Earth Pictures

as the areas of light and shade pass over different areas of the eye in turn.

Though most living creatures have eyes, this does not mean that they see the world as humans do. Light sensitive cells in the compound eye of the bee, for instance, are sensitive to a section of the electromagnetic spectrum that we do not perceive — the ultraviolet section. Thus a daisy looks blue to a bee, not yellow.

Some snakes have cells that are sensitive to electromagnetic radiation in the infra-red band (heat radiation). They can 'see' when there is no visible light by picking up the heat radiated by their potential dinners.

Not all creatures can perceive colours, however; humans and other primates, such as chimps,

have really good colour vision, as do birds, fish, reptiles and insects, including bees and dragon flies. But cats, dogs and a great range of the larger mammals see the world only in shades of grey.

Amphibious creatures — those living in and out of water — have a problem: air and water bend (refract) light in different ways. This means that eyes that work in air won't necessarily work as well in water and vice versa — the image will not be focused on the retina.

To get round this, different creatures have different solutions. Penguins, who rely on acute vision underwater to catch fish, have flat-

The shape of the eye is measured by an optician using a kerometer to test for astigmatism or glaucoma.



Andrew McClenaghan/SPL

or contact lenses. Short sightedness is corrected by a diverging lens and long sightedness by a converging lens.

In another defect, astigmatism, the image is not focused uniformly (at one point) on the retina. This can also be rectified with an appropriate lens that corrects the distortion of the image. As people get older, they tend to become more long sighted. The muscles controlling the lens weaken with age, so they cannot squash the lens down to bring close objects into focus. The answer is converging lenses, which are worn for close work, such as reading.

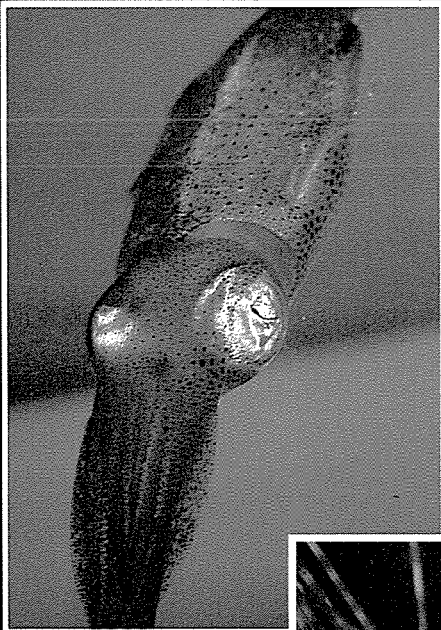
When someone has short sight and needs lenses for close work, they can have bifocal lenses. In these, the lower part of the lens has a different focal length to the upper. Modern multifocal lenses, have a variable focal length over the bottom half so a hard line is not visible where the focal lengths diverge.

THE OPTICAL WINDOW

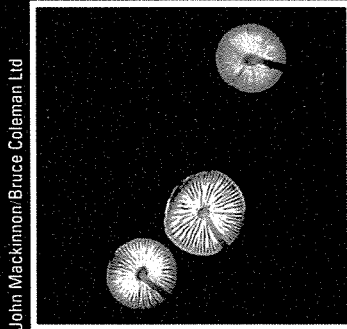
It is not simply chance that we see the range of light wavelengths that we do. The Sun sends out electromagnetic radiation in a wide range of wavelengths, but most of these are absorbed by the Earth's atmosphere. The wavelengths visible to most surface dwelling creatures are the ones that are able to penetrate through the atmosphere. Astronomers call this range of visible wavelengths the 'optical window'.



Jane Burton/Bruce Coleman Ltd



Bioluminescence is the light exhibited by some plants and animals when enzymes within them react with oxygen, as in the fungus below.



John Mackinnon/Bruce Coleman Ltd



Larry Madin/Planet Earth Pictures

Looking like an X-ray, a jelly fish lights its own way in the darkness of the ocean depths. The disadvantage, of course, is that predators can see it, too.

A beacon in the dark, the last few segments of a firefly light up to attract a mate. The colour, intensity and frequency of the glow can vary considerably.

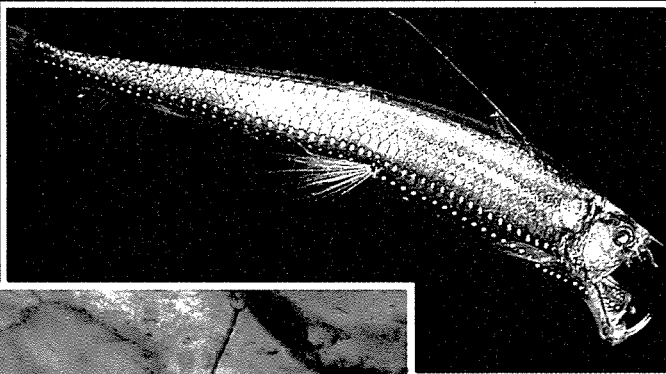
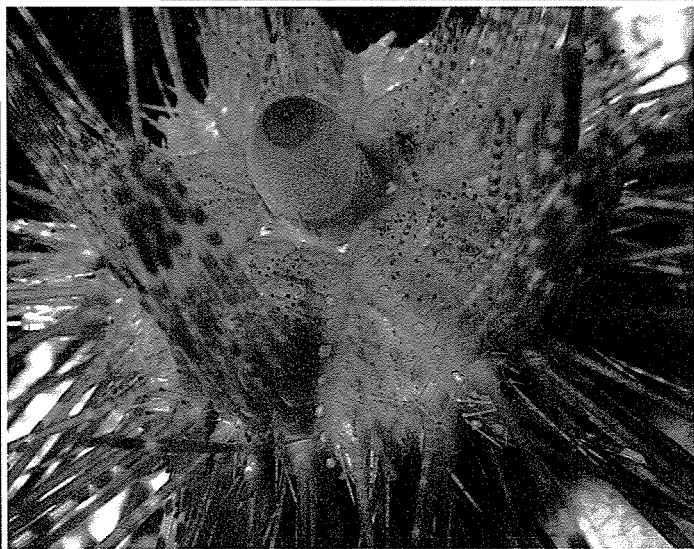


Ivan Polunin/NHPA

In the depths of the sea, where light is scarce, the pop-eyed squid sheds its own glow. This may be to attract a mate or scare away an enemy.

Jane Burton/Bruce Coleman Ltd

Luminescent eyes criss-cross a sea urchin to help it find food in the dark at the bottom of the sea where it lives. Without its own source of light, it would starve.



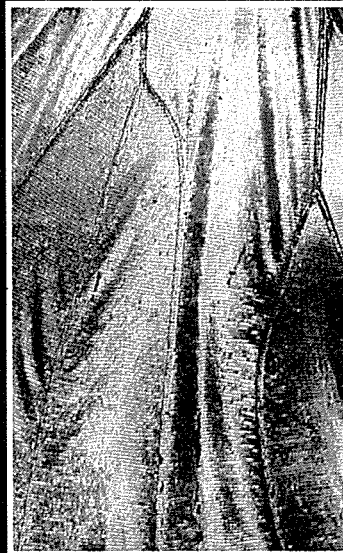
Agence Nature/NHPA

The viper fish can adjust the lights (photophores) on its underbelly to match the light from the surface above. This makes it invisible from below.

Kim Taylor/Bruce Coleman Ltd

Starkly silhouetted, a ground beetle stands out against birchwood that is illuminated by the honey fungus covering it.

Frances Furlong/Bruce Coleman Ltd



G I Bernard/NHPA

Iridescence in a butterfly's wing is caused when some light waves are reflected from the surface and some are absorbed and then reflected from below the surface.

Fireworks are created in a cave as glow-worms flit about. Glow-worms are nocturnal beetles that are luminous as adults and, sometimes, as larvae. They can often synchronize their flashing when in a group.



Q DESERT WATER

Q FOOLING THE BRAIN

Q FALSE COLOUR

Phil Jude/SPL

Peter Aprahamian/SPL

OPTICAL ILLUSIONS

A mirage of water around an oilfield in the desert is caused by hot air close to the ground bending the light.

WITHOUT A DROP OF WATER left in his canteen, the intrepid explorer sees trees and water on the horizon – the promise of life. He stumbles on and on, until the heat and dehydration finally defeat him. What he was trying to reach was a mirage.

Mirages are just one type of illusion where we either see or perceive objects or images that are either not there or not what they seem.

If you stare long enough at a sheet of red paper, then look at a white sheet of paper, the white paper might take on a greenish tint. This happens because the eye and the brain get accustomed to the red paper and try to compensate for the red appearance of what they are looking at by boosting their receptivity to green light. So when you look at the white paper your eyes

are more sensitive to the green content of the light reflected from it – giving it a green appearance.

Similarly, if you look at colours in patterns, look at other patterns or plain surfaces, after-images and false colours can appear where none exist.

Movement illusions

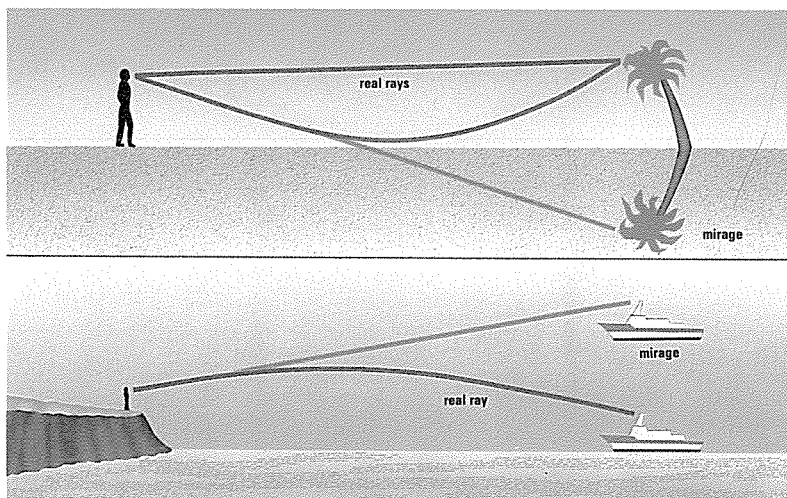
If you stare at the water falling from a waterfall for long enough, then look away to a plain surface where there is no movement, such as grass, you can see what appears to be movement upwards on the plain surface. This is another example of the visual system getting used to one continual input, then when that

input is removed the opposite appearing.

Some theories say that this phenomenon is due to fatigue. For example, the parts of the visual system that are receptive to downward movement become tired, but the sensors that are responsible for detecting upward movement do not. So when the movement stops, the reduced input from the fatigued downward sensors gives the appearance of upward motion.



MIRAGE – THE ILLUSION THAT CAN KILL



Mark Franklin

When the ground is warmed by sunlight, the air close to the ground gets very hot. Hot air is less dense than cold air and denser air refracts (bends) light more than less-dense air – so the atmosphere close to the hot surface acts like a giant lens. This giant lens bends the light from a distant object – which could be many kilometres away

from the observer – back to ground level, making it seem closer than it is.

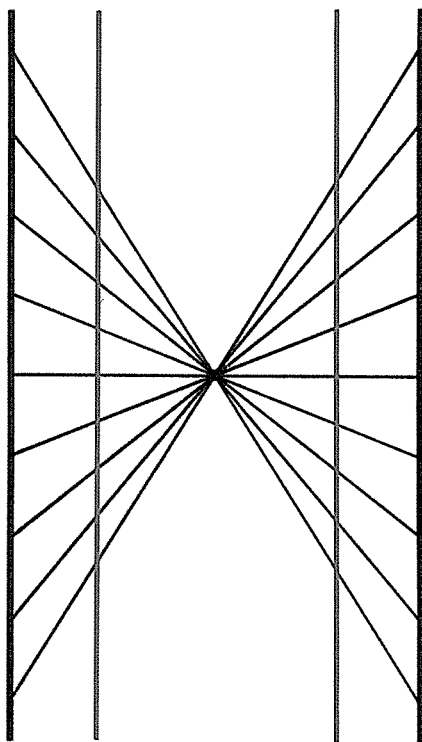
A similar effect occurs when a tarmac road gets very hot. If you look along the road you can sometimes see a shimmering metallic image. This is simply light refracted by the air of different densities close to the hot surface of the road.

shapes of equal length or size appearing to be different. Normally visible objects can also be made to disappear.

Fooling the eye into seeing images in three dimensions is not too hard. One old-fashioned way of doing this is the stereoscope. This uses pairs of colour slides viewed through lenses – one is seen through the left eye piece, the other through the right.

The pairs of slides are taken by a camera with two lenses and two rolls of film. Its lenses are spaced the distance between your two

The vertical blue lines appear bent – but only because the brain expects a curved line on the end of an array of spokes.



John Woolford

Pictures of impossible objects are another good example of optical illusions. In some paintings impossible things happen, such as people walking up endless staircases. These visual tricks are performed by the use of false perspective – the brain tries to make a three-dimensional image out of what is, in fact, just a series of lines on paper.

Other illusions can show straight lines bending (see above), perfect circles being distorted and lines and

The Walt Disney Company



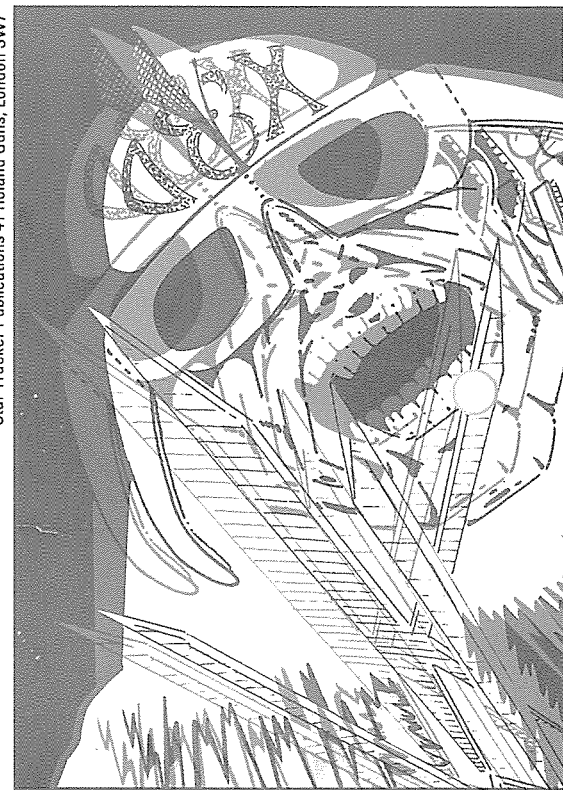
The illusion of 3-D can be given by printing two slightly different images – one in red, one in green. Glasses with one red lens and one green lens (left) ensure that one eye sees only the red image and the other sees only the green.

3-D movies can be made in the same way. Each frame has two slightly different images, filmed by two cameras, mounted side by side, whose lenses are the same distance apart as your eyes.

eyes apart. When the slides are viewed simultaneously, they present the viewer with a pair of images just different enough to give three-dimensional appearance to the objects shown. The two views are what your two eyes would see if you were standing where the camera was.

On the Moon

The American astronauts walking on the Moon in the late 1960s and early 1970s had a problem judging distances. The distance of far away objects is not judged by the eyes focusing or swivelling slightly so that they are both pointing at the object you are looking at – it is other clues that tell how far they are away. On Earth, one of the most important of these clues is the fact that air gets less clear further away.



Star Tracker Publications 41 Roland Gdns, London SW7



THE TROPICAL FOREST



EVOLVING JUNGLE

IN THE JUNGLE, DEATH threatens at every step. The air is hot and damp, huge trees soar 30 metres or more into the air, venomous snakes curl around the branches, monkeys chatter and parrots screech.

In the dense undergrowth all manner of fierce or poisonous animals hide, ready to bite or attack with



FOREST LAYERS

claws and teeth. However, popular myth has clouded reality, for not all jungles are the same. They vary greatly in different parts of the world. Scientists now use more accurate terms, such as 'tropical rain forest' or 'subtropical montane cloud forest', to describe what most people call a 'jungle'.

Tropical rain forests are in the



DEFORESTATION

tropics, of course. This means they grow between the Tropics of Cancer and Capricorn, in a narrow band around the Earth on either side of the equator. The climate is warm throughout the year, with average temperatures of about 20–28°C.

True tropical rain forests grow only in the lowlands, not high up on mountains. This is because as you

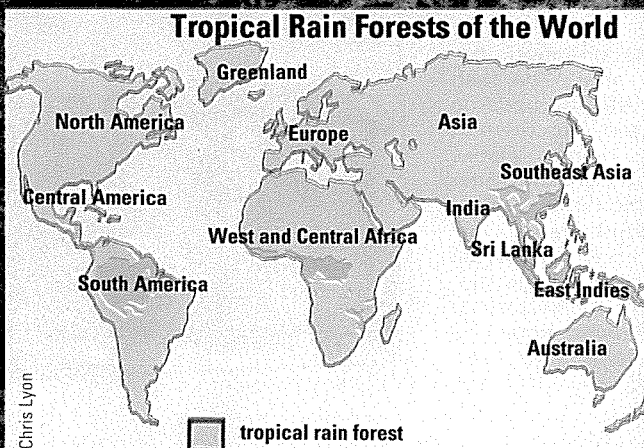
Victor Englebert/Survival International

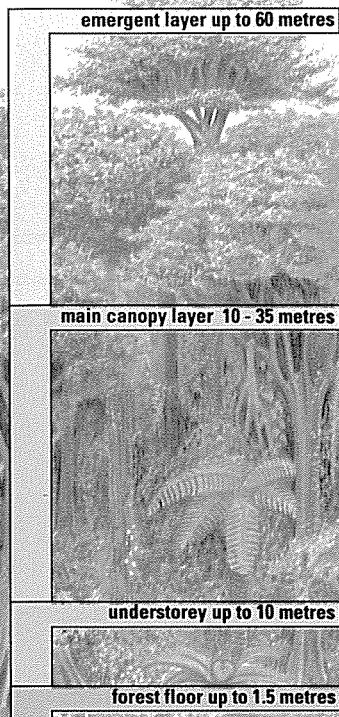
Partridge Films Ltd



The Yanomami Indians of the Brazilian rain forest use hunting skills passed down through generations. Their longbows are made of palm wood with strings from the bark of coca ash trees: the arrows are sharpened bamboo canes. A typical quarry is the white-lipped peccary, a kind of wild pig.

The forest canopy and dense understorey of the jungle of Brunei in the East Indies provides shelter and protection for many species.





The Struggle for Light

Jungle vegetation struggling for light forms four distinct layers. The forest floor – a thin layer of decaying leaves and animal remains – eventually becomes soil. Shrubs, mosses and small trees form the understory. Above these is the forest canopy – the branches and leaves of the tall evergreen trees. Towering above everything are the giant trees of the emergent layer.

Mark Iley

travel up a mountain, the temperature falls and it is not warm enough for a true tropical forest to grow – even in a tropical region.

The third main feature of tropical rain forests is rain. The rain falls

great dinosaurs, evolved to suit the conditions of the time.

Slowly, over millions of years, Gondwanaland split up and the pieces drifted apart to form the continents as we know them today

Vast numbers of animals live in every layer of the jungle. They all depend on each other and on the vegetation that supports them – and they are not found anywhere else.

When a large patch of tropical rain forest is cut down, it may take up to 400 years to grow again. At first the quick-growing 'pioneer' plants cover the clearing. Then in about 10 or 20 years various small trees and shrubs grow. The giant trees grow much more slowly, struggling through the low vegetation to reform the canopy. Then vines and creepers re-establish themselves and the thousands of animals that can only live in the rain forest return.

Sadly, such enormous areas of rain forest are now being cut down that there is little chance that they will be able to heal themselves.

The strangling fig tree sends roots down the trunk of its host. As they thicken the host tree dies and rots.



Jeff Foote/Bruce Coleman Ltd

Bromeliads are distant relatives of the pineapple. Their leaves form ponds used by a host of little creatures.

throughout the year rather than in one wet season. In general, rain forests grow where the rainfall is more than 1,800 mm each year. A tropical storm can pour down 200 mm of rain in one hour.

Jungle birth

These huge amounts of water are soaked up by the forest trees and other plants. They also 'breathe' water vapour from their leaves back into the atmosphere, which forms more clouds – and so more rain.

Tropical rain forests have been on Earth for more than 75 million years. At that time, two thirds of the giant 'supercontinent' called Gondwanaland was covered by forests. Thousands upon thousands of plants and animals, including the

The world's climate changed, becoming colder and drier. The lush tropical forests gradually became smaller and separated into distinct 'pockets'. Animals and plants evolved to fit conditions in their own locality. But then the climate warmed up again and became wetter, so that the pockets of forest gradually grew back together. These changes probably happened several times, and over time the forest life became richer and more varied.

Just amazing!

NO VACANCIES!

A HUNDRED TIMES MORE LIFE FORMS CROWD INTO A TYPICAL 4 SQ KM PATCH OF TROPICAL RAIN FOREST THAN WOULD BE FOUND IN A COMPARABLE PATCH OF EUROPEAN FOREST.



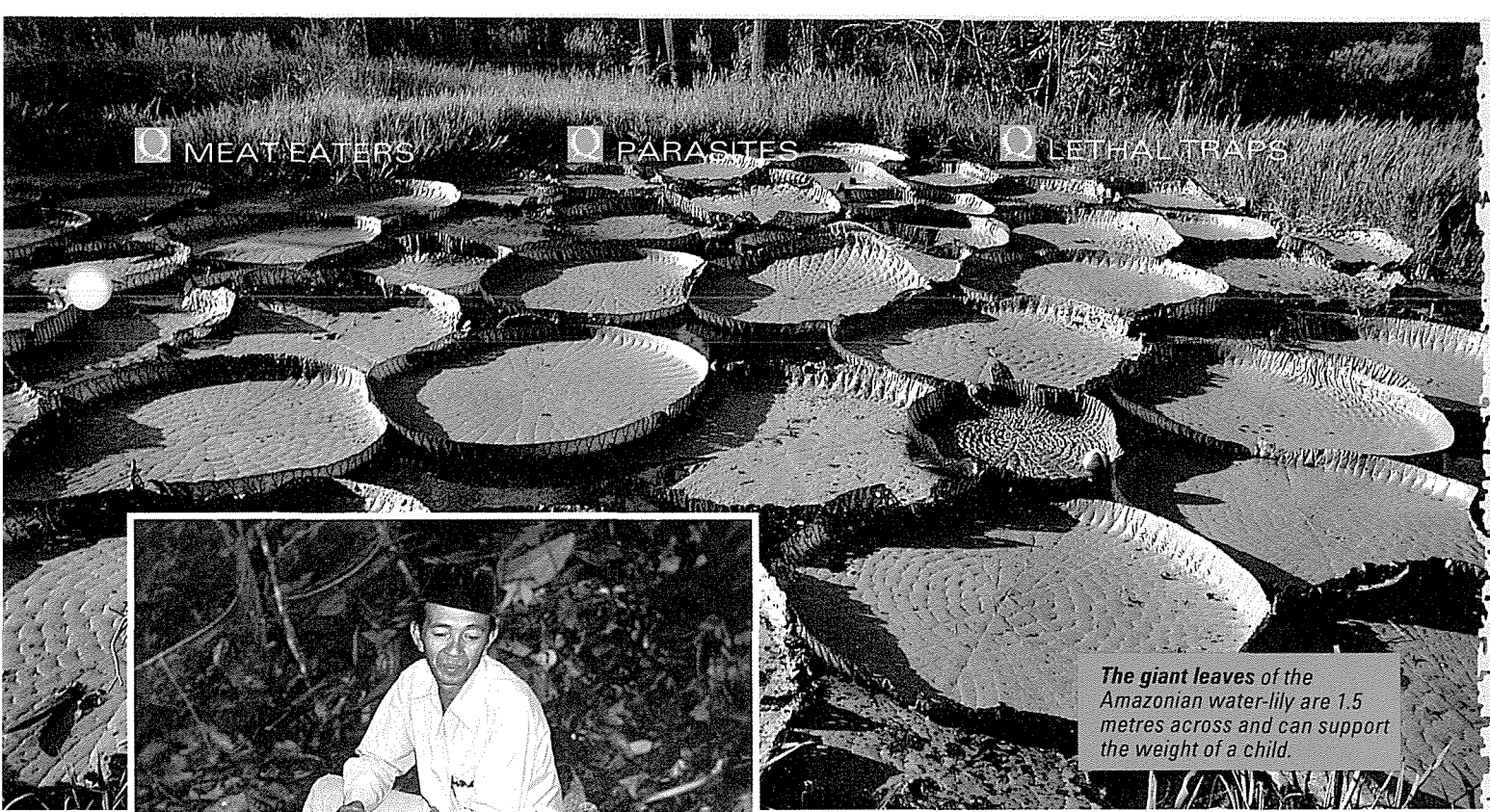
Paul Raymonde



Q MEAT EATERS

Q PARASITES

Q LETHAL TRAPS



The giant leaves of the Amazonian water-lily are 1.5 metres across and can support the weight of a child.



M W F Tweedie/NHPA

PLANT POWER

Hutchison Library

PLANTS SUPPORT LIFE ON Earth. They capture the Sun's energy and use it to power chemical reactions in which simple chemicals are built up into living tissue.

All animals depend on plants. They either eat them or they eat another animal that has eaten a plant. Nowhere are plants more numerous than in the jungle.

Staying upright

Forest trees need to be tall in order to receive the energy-giving sunshine from above. They also need nutrients from the soil beneath them – but rain forest soil is very shallow, since leaves and other debris rot away so quickly in the warm, damp conditions. Therefore forest trees do not have long, deep roots and staying upright can be a problem.

Some trees, such as the silk cotton tree and giant oje fig tree, have solved the problem by having buttresses – large flanges or wedges that stick out from the lower trunk, spreading sideways to make the base of the tree broader.

In especially poor soils, some plants get the nutrients they need

The aerial roots of an epiphytic orchid are designed to hang from tree-tops and absorb moisture from the humid air.

The biggest flower in the world – the rafflesia – weighs 6 kg and is 1 metre across. Its putrid smell of rotting flesh attracts flies.

by eating meat. They trap small animals by all sorts of ingenious snares. Pitcher plants trap and digest insects in their deep, pot-shaped 'pitchers'. Pitcher plants that grow in the wet jungles of Borneo root in the forest floor and send shoots 15 metres up into the trees, or germinate in crevices in the bark of trees high in the canopy.

Paul Claxton/Orpix



The 'pitcher' is made from the shaped end of a leaf, with a narrow neck and a lid. Inside, it is about one-third full of a lethal acidic liquid that contains a special chemical, the enzyme trypsin, which dissolves the protein that makes up the tissues of an insect. There are many kinds of pitcher – some are up to 30 cm long and hold 1 litre of fluid.

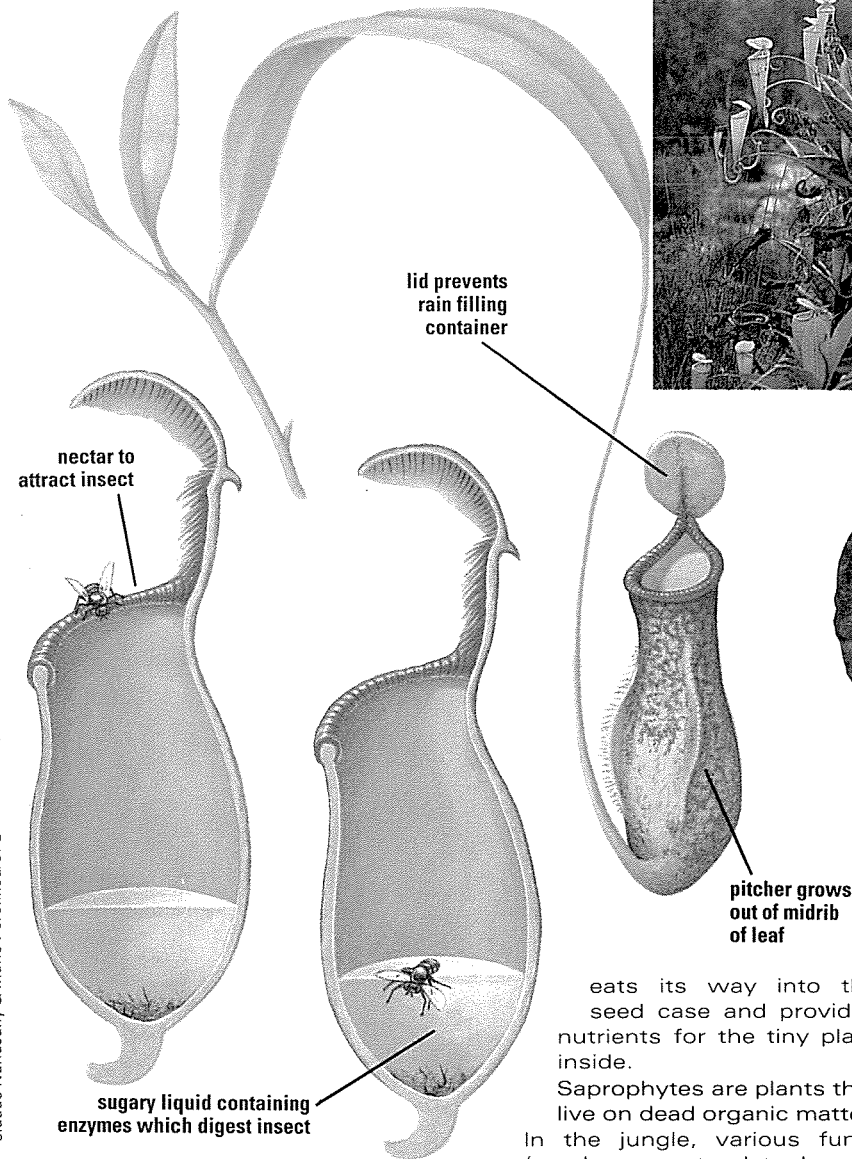
Into the light

Epiphytes are plants that grow high up in the branches of trees to overcome the lack of light on the forest floor. They do not take nourishment from the tree, as a parasite would, but use it only for support. By doing this, however, they give up the usual method of absorbing nutrients and moisture from the soil through their roots.

The orchid family includes a number of typical epiphytes. This is one of the largest families of flowering plants – there are over 30,000 species – and most of them grow in warm, humid tropical regions. Many

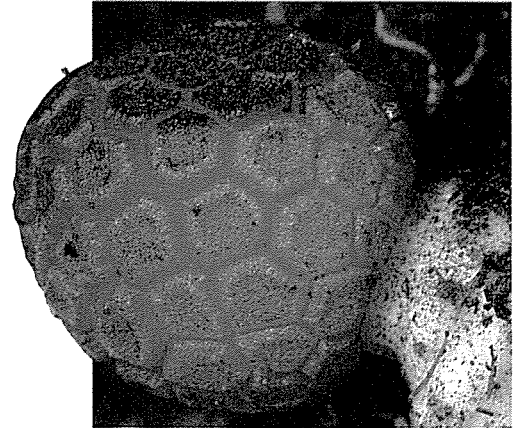


How a pitcher plant feeds



Carnivorous pitcher plants attract insects with their nectar and bright colours. Unlucky insects drown in acidic liquid in the urn-like traps and are then digested.

This parasitic flowering plant from Ecuador takes all its nourishment from the roots of forest trees.



Dr Morley Read/Science Photo Library

with a tiny wasp. These trees have three sorts of flower – a male, female and gallflower. The gallflower provides a safe home for the gallwasp larva. The adult gallwasp carries the pollen from the male flower to the female one.

A lichen is a partnership between a fungus, the main body, and an alga, which forms a layer near the surface of the fungus. Together they grow more slowly and live longer than they would apart. In jungles lichens grow on tree trunks, absorbing moisture and nutrients from rainwater.

have aerial roots, which hang down in mid-air from the tree tops and absorb moisture from the humid air. Others have roots that cling to the bark of the tree in a dense tangle to trap bits and pieces falling from the canopy above.

Orchid seeds are so tiny that three million would weigh just 1 gm. They spread on the breeze, but they cannot germinate and start to grow without a special fungus that

eats its way into the seed case and provides nutrients for the tiny plant inside.

Saprophytes are plants that live on dead organic matter.

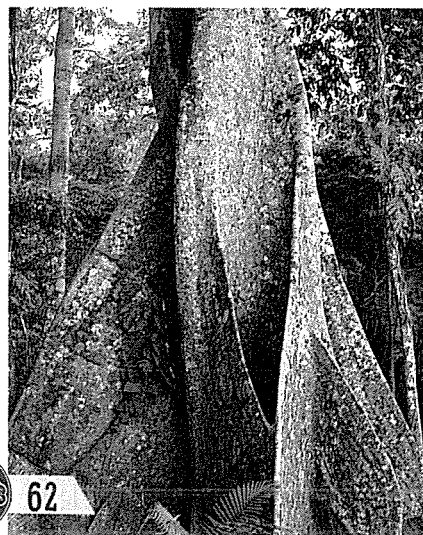
In the jungle, various fungi (mushrooms, toadstools and the like) are the main saprophytes. They are a vital link in the cycle of nutrients, helping to break down dead plant and animal tissue so that the nutrients go back into the soil, ready to be used again by the trees.

Unlike saprophytes, which eat dead things, parasitic plants get their nourishment from a living host. The rafflesia flower is a parasite of vine roots. It receives no sunlight and must, therefore, get its energy from another source. Its roots eat into and suck nutrients from the roots of cissus vines. The only part that shows above the ground is the flower.

Living together

When two things live together in a mutually beneficial partnership, this is known as a symbiotic relationship. Symbiotic associations are common in the jungle. For example, certain fig trees live symbiotically

Support is essential for rain forest trees that grow up to 30 metres tall. They use their own roots to keep them upright.

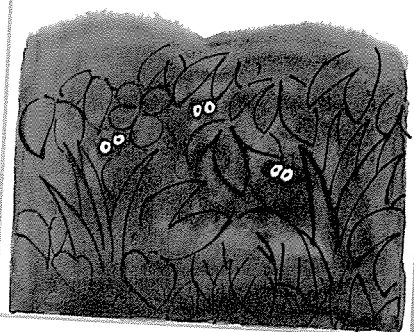


Tony Morrison/South American Pictures

Just amazing!

SEARCH LIGHT

JUST TWO PER CENT OF LIGHT FROM THE SUN FILTERS THROUGH TO THE FOREST FLOOR – THE DENSELY PACKED TALL TREES PREVENT ANY MORE GETTING THROUGH.



Paul Raymonde





-  RAVENOUS ANTS
-  GIANT SNAKES
-  KILLER SPIDERS



Survival is the name of the game in the jungle. Small birds fall prey to giant spiders, while tiny plants flourish on the tresses of a sloth (above).

WILD LIFE

LIFE TEEMS IN AND AROUND the trees of a rain forest. Different types of mammals, birds, reptiles and amphibians, and vast numbers of insects live closely at every layer in the forest, dependent on each other and on the trees around them.

Animals such as monkeys, birds, butterflies and flies, that live in the top layer – the jungle canopy – lead noisy and colourful lives. Lower down in the branches are snakes, frogs, insects, slugs and snails that creep among the humid trailing vines.

On the forest floor, insects, worms, millipedes and other small creatures eat the debris that rains from above. In every layer, any animal that is not wary enough can suddenly find itself becoming a meal for someone else.

Swinging about

Most jungle monkeys live in groups, howling and screeching to each other as they search for food, or warn members of their troop about enemies such as kites, eagles and snakes. Their long arms, strong

hands and gripping thumbs enable them to swing from branch to branch at great speed through the treetops.

Monkeys see in colour so that they can spot the bright, ripe fruits they feed on from far away. With two forward-pointing eyes, they can judge distances accurately as they jump from tree to tree. Good eyesight also helps in seeing

whether a branch is old, rotten and about to crack – which can mean a fall to the ground 50 metres below, and almost certain death.

High in the canopies of South American rain forests live the sloths. These curious creatures move slowly and deliberately through the trees, hanging upside down by their long, curved claws. A sloth is almost impossible to see

YELLOW SPELLS DANGER

How can apparently defenceless creatures like these frogs sit calmly in full view of any passing jungle hunters? The answer is in their colouring. For the vivid yellow and black of the Arrow-Poison Frog of Venezuela is a potent warning to potential predators: their harmless-looking skin actually secretes a deadly poison. Yellow (and especially yellow and black) is often used in the animal kingdom as an effective warning signal. Together the two colours create a distinctive, easily-recognized pattern that warns other animals – and humans – to keep their distance, or else suffer the deadly consequences.





among the leaves, because its hairs are coloured green by algae (tiny plants) growing on them. The hair hangs downwards so that the rain runs off it easily.

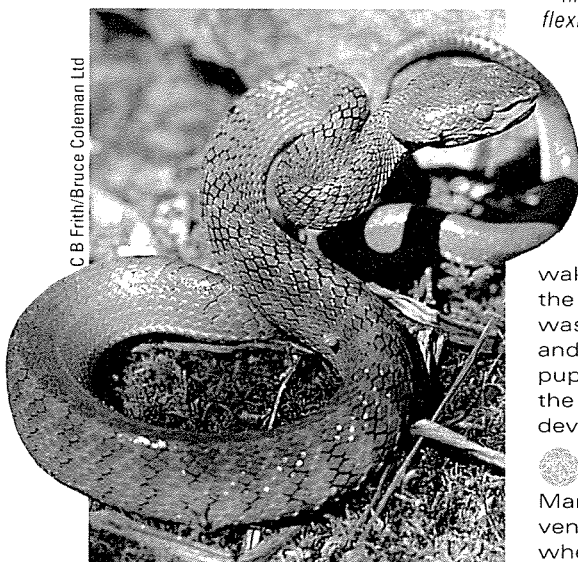
Sloths use very little energy, so they do not need much food. Each sloth prefers the leaves of a certain plant, which means that the sloths in one area do not all try to eat the same food. The meal is digested in a huge stomach, which contains bacteria that dissolve the tough plant material. One meal may stay in the

Nothing is wasted in the jungle. Two wasps gorge themselves on the blood of a peccary (a kind of wild pig).

A prehensile (gripping) tail acts as an extra limb for the common woolly monkey, which lives in family groups high in the trees. The flexible tip also bears a fingerprint.



Alan Root/Survival Anglia Ltd



The Asian green pit viper blends deceptively into the foliage. Explorers have told of pushing aside harmless branches only to find the poisonous snake underneath.

wake. Some parasitic wasps use the ant larvae as living larders. The wasp manages to get into the nest and lay its eggs in the ant larvae or pupae. The ants are then eaten from the inside by the tiny wasp grubs developing within.

Beware poisons!

Many jungle creatures rely on venom, either to defend themselves when attacked, or to inject into their prey, to paralyse or kill it. The venom of some snakes is a neurotoxin – it prevents the victim's nerves from working properly so that it cannot make any movements at all, sometimes not even breathe.

One example is the Gaboon viper from Africa – the largest of all vipers. Its body is 2 metres long and up to 15 cm thick. The vivid pattern on its back blends in with the leaves on the forest floor, providing the perfect camouflage as it waits to ambush frogs, birds and mice. This species also has the longest fangs of any snake: up to 50 mm in length.

Tropical bird-eating spiders hunt among the jungle branches for nestlings and small birds. Their bite can easily kill a humming-bird, but it is

not much worse than a bee sting to humans. If you try to handle one of these spiders, however, its hairs break off and cause terrible itching, swelling and skin irritation.

The largest bird-eating spiders are more than 25 cm across. They have various names – tarantulas in America and baboon spiders in Africa. They also eat small insects, frogs, snakes and other spiders.

Another fearsome hunter of the rain forest is the giant Malayan centipede. This grows up to 20 cm long and its movements are almost too quick to follow with the eye as it dashes through the leaves. Its bite has been known to kill a human.

Millipedes are close relatives of centipedes, although they eat rotting leaves rather than hunt for prey. Their venom is used in defence. Some rain forest millipedes can spray a poisonous fluid up to one metre.

stomach for up to a month. A sloth only urinates and defecates about once each week, in the same place – usually at the bottom of a tree.

An army of ants

Army ants live in vast colonies on the jungle floor. The colonies are so big that they rapidly devour all the food in an area, so they must soon move on. When the colony, or army, is on the march, any animal in its path must either get out of the way – or be eaten alive.

However, many creatures need army ants for their survival. Birds, butterflies and wasps follow the raiding parties and clean up after the ants, feeding on the dead or dying plants and animals left in their

Just amazing!

MASSED RANKS

A SINGLE COLONY OF ARMY ANTS MAY CONSIST OF MORE THAN 20 MILLION INDIVIDUALS – MORE ANTS THAN ALL THE INHABITANTS OF MEXICO CITY, THE WORLD'S MOST POPULOUS CITY.



HOW TO REPRODUCE

Dozens of sperm become stuck to the egg's jelly coat, which is made of glycoprotein, before one sperm penetrates it. The rest die and waste away.

Gamma/Frank Spooner Pictures

MULTIPLE FISSION

ALL PLANTS AND ANIMALS need to reproduce. In this way, they make one or more copies of themselves and so make sure that others like themselves – the species – continue to survive.

The most basic living unit of virtually all living things, whether plant or animal, is a cell. To reproduce, cells must multiply. They do this by dividing themselves up.

But the word, 'division' can be misleading. New cells are not simply made up of half the ingredients of the original cell – that would make the new cells weaker and, therefore, unlikely to last long in the constant battle for survival.

Instead, when a cell first divides into two and those two into four, and so on, it remakes the ingredients of the original cell. In this way, the new cells – known as daughter cells – become very similar to the parent cells.

At the heart of every cell is a densely packed globule, the nuc-

SEX CELLS

leus. The nucleus is very important in reproduction as it houses *chromosomes*, and it is the chromosomes that carry the information for making daughter cells similar to parent cells. The information that will make daughter cells similar to the parent cells is transmitted in a code by the *DNA* (deoxyribonucleic acid) within the chromosome.

Cell fission

Plants and animals can reproduce themselves in two ways. These are known as sexual and asexual reproduction.

In asexual reproduction, the original cell can sub-divide and form yet another cell. This is known as *binary fission*. Extremely simple one cell plants, such as the blue green algae, do this. Bacteria too are single-celled. Under perfect condi-

Frog spawn clusters may contain as many as 30,000 eggs. The male clasps the female and sheds his sperm over them.

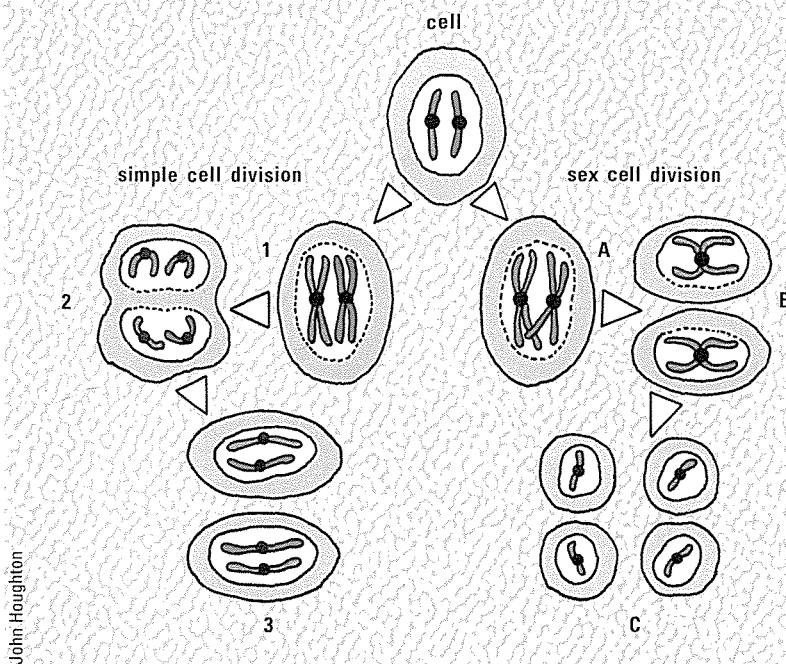
INTERNAL FERTILIZATION



G I Bernard/Oxford Scientific Films



THE THREE STAGES OF CELL DIVISION



Simple cell division creates two identical cells from one.

- 1 All the chromosomes duplicate
- 2 The nucleus divides into two, each new nucleus containing one full set of chromosomes
- 3 The rest of the cell divides into two, around the nuclei

Sex cell division creates egg and sperm cells.

A Each chromosome duplicates itself and intermingles with another pair, swapping bits with each other. The intermingled pairs split apart again.

B The cell divides as in simple cell division, so that there are the same number of chromosomes in each new cell as in the original cell

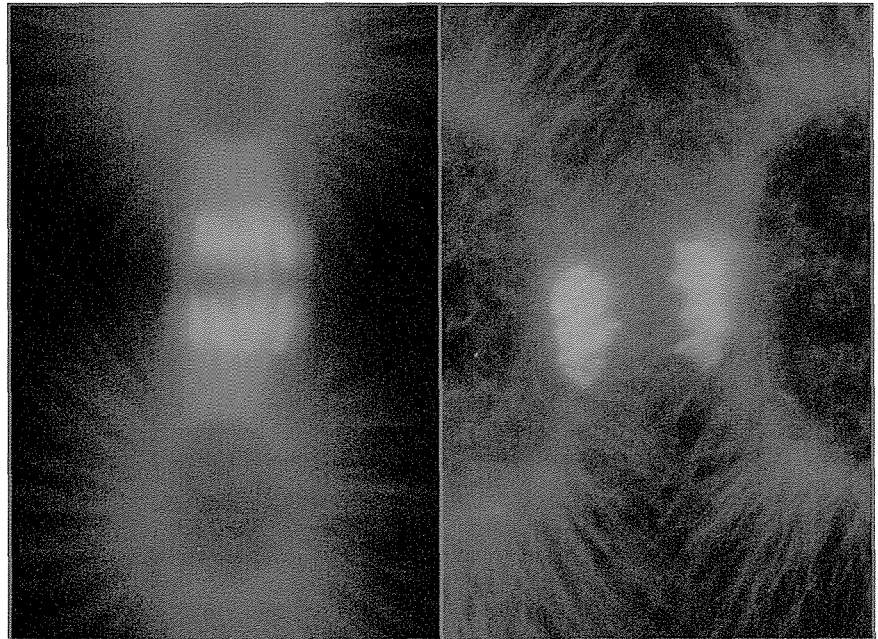
C These two cells now divide *again*, without doubling the number of chromosomes beforehand. The new sperm or egg cells have half the number of chromosomes of the original.

tions, bacteria can double about every 20 minutes. This means that after 24 hours, a single cell would have given rise to more than 4,000 million million million offspring!

Another form of asexual reproduction is known as *multiple fission* because the nucleus divides repeatedly. Each new nucleus moves out of the cell, carrying with it a part of the original cell. In this way, new cells are formed, each with their own nucleus. For example, the cell

NO SEX PLEASE

Not all eggs need to be fertilized by a sperm to produce an offspring. Honey bee drones are fertile males that develop from unfertilized eggs laid by the queen. This method of reproduction is known as *parthenogenesis* (from the Greek for virgin birth).



Simple cell division takes about an hour. The chromosomes (stained blue) divide into two and then separate to the opposite ends of the cell (stained green). The cell divides to form two new cells.

bearing the disease malaria, the malarial parasite, can produce as many as 1,000 offspring when it invades the liver.

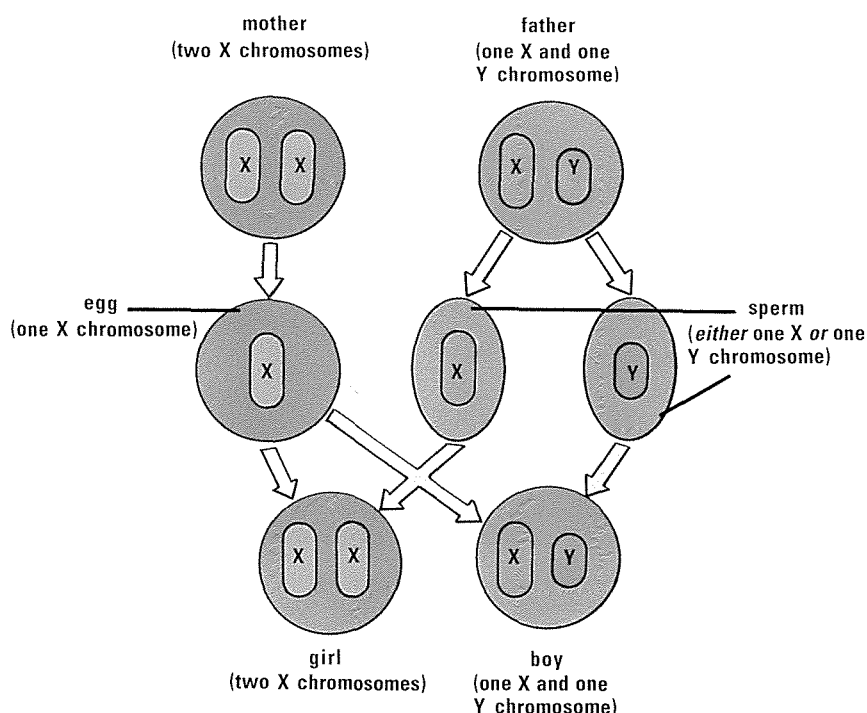
Tiny spores

Some bacteria and other single-cell organisms, along with many plants, reproduce asexually by forming single cell bodies called spores. These leave the parent body and when they find the right conditions for germinating, sprout new offspring. Spores are usually very small and light so that they can be transported on the wind or by water and animals. Moss, ferns and many types of fungus reproduce by releasing spores.

Budding is yet another way of reproducing asexually. Yeast and many very simple animal life forms, including some worms, develop an



WHY BOYS ARE BOYS AND GIRLS ARE GIRLS



A woman has two X chromosomes in each of her cells, but a man has one X and one Y chromosome in each of his. Therefore an egg always contains one X chromosome, but a sperm may have one X or one Y.

If an egg is fertilized by a sperm

carrying an X chromosome, the result is XX – a girl. But if the egg were to be fertilized by a sperm carrying a Y chromosome the result would be XY – a boy. The only sure way to guarantee the sex is to fertilize in a test tube and implant the egg.

outgrowth that then detaches itself and continues life on its own.

Some plants and animals literally break apart to form a new generation. This is known as fragmentation. For example, a marine worm, the nemertine *Lineus*, develops rings around its body during spring and summer. These rings tighten around the body causing bits to break off. As these bits develop into new worms, they too break up in

the same way, so that one original worm could be the parent to hundreds at a time.

Often, if you take the leaf off a plant, or cut off a part of its stem, and replant it, another similar plant will grow directly from it – there is

A yeast cell multiplies by budding. Yeast is used to brew beer and make bread rise by converting sugars into alcohol and carbon dioxide.

no need to plant the seeds. This process of asexual reproduction is known as vegetative propagation.

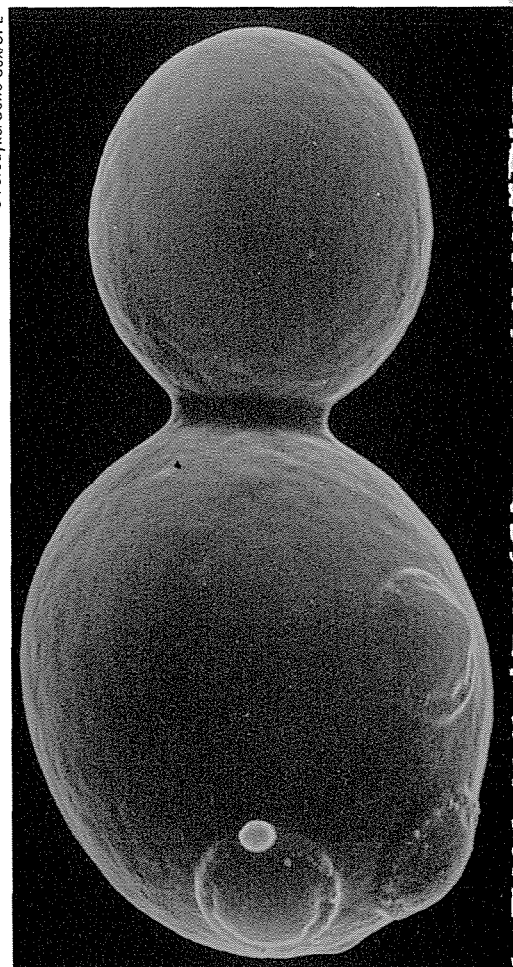
This is just how potatoes are reproduced. The part of the potato that we eat is called the tuber. The 'eyes' on the potato are buds; if the potato is planted, each eye can produce a new shoot the following year using food stored in the tuber.

Asexual reproduction may be useful for very rapid multiplication, but it has its disadvantages: the offspring is identical to the parent. This means it cannot develop differently (evolve) to meet the challenge of changing circumstances

Yellow bristles trap pollen coated flies in the hollow base of the arum lily's spadix (central spike), together with the male and female flowers of the plant.

and situations – in the weather or environment, for instance.

This problem is solved by sexual reproduction. Here, two specialized sex cells – the *gametes* – from two different sources (the male and female) come together. This means that the new plant or animal can inherit characteristics from both parents in different combinations. The number of different combinations of characteristics will keep increasing with each generation. Therefore, when circumstances change at least some of the offspring will have



J Forsythe/Gene Cox/SPL



G I Bernard/Oxford Scientific Films

the right combination of characteristics to cope with the change.

For sexual reproduction to take place, the gametes must fuse properly if they are to create new life. When male and female gametes fuse, their two nuclei, each containing their own set of chromosomes, are brought together. The result, through fertilization, is a new cell and, eventually, the new many-celled plant or animal that will emerge.

When gametes fuse

The actual process is similar in both animals and plants. When the head of the male gamete (the sperm) hits the surface of the female gamete (the egg), an enzyme which softens the surface of the egg is released and the sperm is sucked into the egg. The membrane



surrounding the egg thickens immediately and so prevents any further sperm from entering. The sperm's tail is usually discarded and the male nucleus is drawn towards the female nucleus.

In the water

The simplest way to bring together male and female gametes is to release them in water. Here they fertilize outside the parents' bodies. This is known as external fertilization. Most creatures that live in water, such as fish, and land living animals that return to water to breed, such as frogs, reproduce through external fertilization.

In most land animals, sperm from the male fertilizes the egg in the female body. This is known as internal fertilization. Internal fertilization needs a male organ, such as a penis, to penetrate the female and transmit the sperm.

In internal fertilization, the sperm have a better chance of meeting with eggs. Also, the fertilized egg is protected. It may be encased in a shell while in the mother's body and after laying, as is the case with birds. Or, as in nearly all mammals,

A new-born kangaroo can be only 2 mm long. Still with umbilical cord attached, the long climb to the mother's pouch begins. Once in the pouch, the young animal can suckle milk and continue growing.



it may be protected by the mother's uterus during its development.

A well known exception is the duck-billed platypus, a mammal found in Australia, which lays eggs and then provides milk for the offspring when they hatch.

Most plants and some animals

have both male and female sexual organs. They are known as hermaphrodites. In order that they should not fertilize themselves, they have evolved some rather elaborate procedures.

Attractive aroma

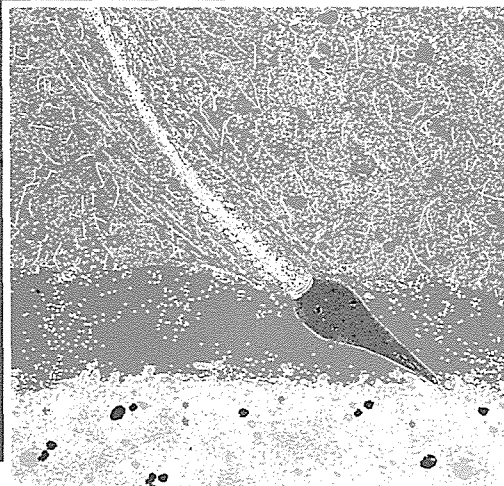
The arum lily, popularly known as lords and ladies, produces a pungent smell to attract hairy moth flies. The fly, covered with pollen from other arum lilies, is trapped within the female part of the flower until pollination is complete – and they remain trapped for a further 12 hours while the male part of the flower ripens. When the flies finally crawl out, they are once again covered with pollen. The flies carry the pollen to the next arum lily to which they are attracted.

The common earthworm is hermaphrodite, having both ovaries and testes present in the same individual. So when two earthworms mate, the eggs of each one is fertilized by sperm from the other.

A large nucleus, containing 23 chromosomes made from DNA, nearly fills the head of each human sperm. The head is attached to a tail which, lashing from side to side, pushes the sperm forward.

A human sperm has just penetrated the thick membrane that surrounds the egg under its jelly coat. The sperm head is about to enter the yolk substance inside the membrane.

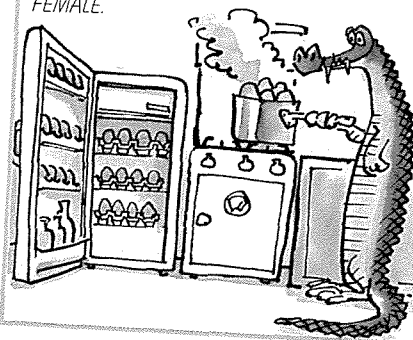
Petit Format/CSI/SPL



Just amazing!

HOT NIGHTS, COOL KIDS

THE SEX OF SOME LIZARDS, ALLIGATORS AND CROCODILES CAN BE DECIDED BY THE TEMPERATURE AT WHICH THE EGGS ARE INCUBATED. HIGH TEMPERATURES MEAN A MALE; LOW TEMPERATURES, A FEMALE.



Paul Raymond



SEXUAL CHEMISTRY

PHEROMONES

SEX HORMONES

TIMELY EVENTS

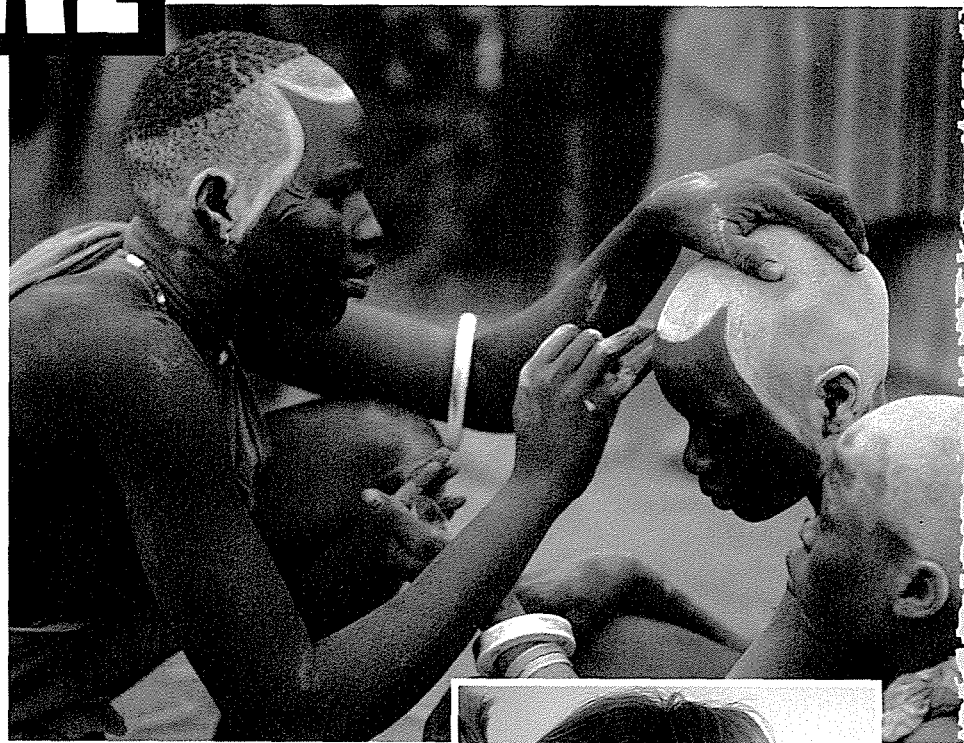
STRANGE, AWKWARD, EVEN violent it may be, but sexual reproduction – from attraction and mating to gestation and birth – is largely under the careful control of chemicals.

Pheromones are chemical substances that are produced by one animal in order to influence the behaviour of another. They are produced by glands and excreted to the outside of the body, for example in sweat or urine. The best known pheromones act as sexual signals. The female gypsy moth produces a pheromone called gyplure which, depending on the wind, will attract a mate from up to 3 km away.

In other species pheromones may function as a repellent. Dogs are one of many animals that excrete substances in their urine, which serve as territorial markers, warning other dogs off. In this way the dog will claim all the bitches in his territory.

Invisible invitation

The existence of pheromones was proved in experiments with cockroaches. When an unmated female cockroach has crawled over a piece



Sexual attraction for many animals depends largely on appearance. In humans this varies greatly between cultures in Africa and the West (right).

of paper, the paper alone is sufficient to arouse courtship behaviour in a male cockroach. The path of the female is marked invisibly with the chemical substance, which stimulates males to court her. In one particular domestic trap this courtship behaviour is turned against the cockroach by using an attractive chemical extracted from cockroach faeces as bait.

Mouse scent

Pheromones excreted in the urine of male mice are designed to perform two distinct, but complementary, tasks. One has the effect of encouraging the female to mate; another causes abortion in pregnant females so that the new male can mate and produce his own offspring.

Hormones, like pheromones, are powerful chemical substances that influence an animal's behaviour.

Pheromones are odours used by many species to attract mates. The antennae of the male American Moon Moth can detect the smell of a female over 3 km away.



Unlike pheromones, however, hormones are not excreted from the body but secreted into the bloodstream. Therefore, they directly influence the animal's own behaviour.

What is true for other animals is true in this case for Man. Given the right stimulus – a fleeting memory, fantasy or a real-life companion – hormones in the male and female of the species will produce, quite automatically, the whole pattern of sexual arousal that, barring intervention, culminates in the act of intercourse. It all starts in the limbic system – a network of nerve cells in the base of the brain. Its stimulation sends messenger chemicals down through the body to trigger the release of the sex hormones.

In the male this is known as

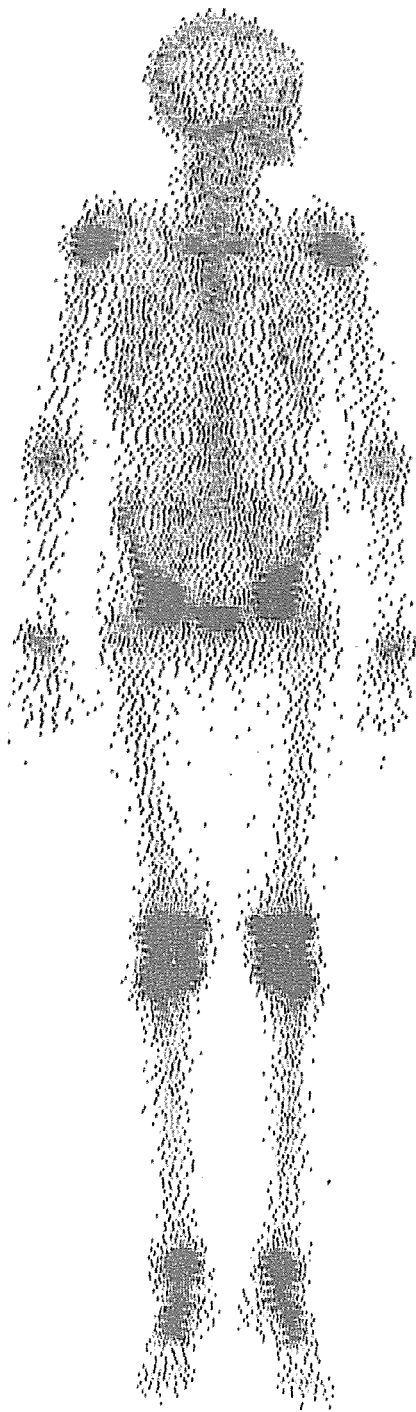


G J Cambridge/NHPA

Hutchinson Library

Tony Stone Photo Library, London





Sex hormones stop the main bone growth throughout the body. This gamma-ray picture shows in red the normal active growth of the long bones. After puberty, when sex hormone production is increased, the red fades away as growth is halted.

Crystals of testosterone, the male sex hormone – magnified 30 times. Its production at puberty stimulates the growth of the male genitals, an increase in body and facial hair, the deepening of the voice and an increase in the muscle mass.



David Parker/SPL

only one reaching maturity every month, however, only about 400 are likely to complete their development. Of these only a very small number are likely to be fertilized. At around the age of 50, women experience the menopause and stop producing eggs altogether.

Like in any complex manufacturing process, the timing of events during reproduction are crucial. Here again it is hormones that

control just when, for example, the uterus (womb) wall is ready to receive the fertilized egg, the changes in the uterus during pregnancy and the onset of milk production after birth. The most obvious example of hormone controlled timing, however, is the cyclical repetition of events in the human female known as the menstrual cycle.

It all starts with the pituitary, a

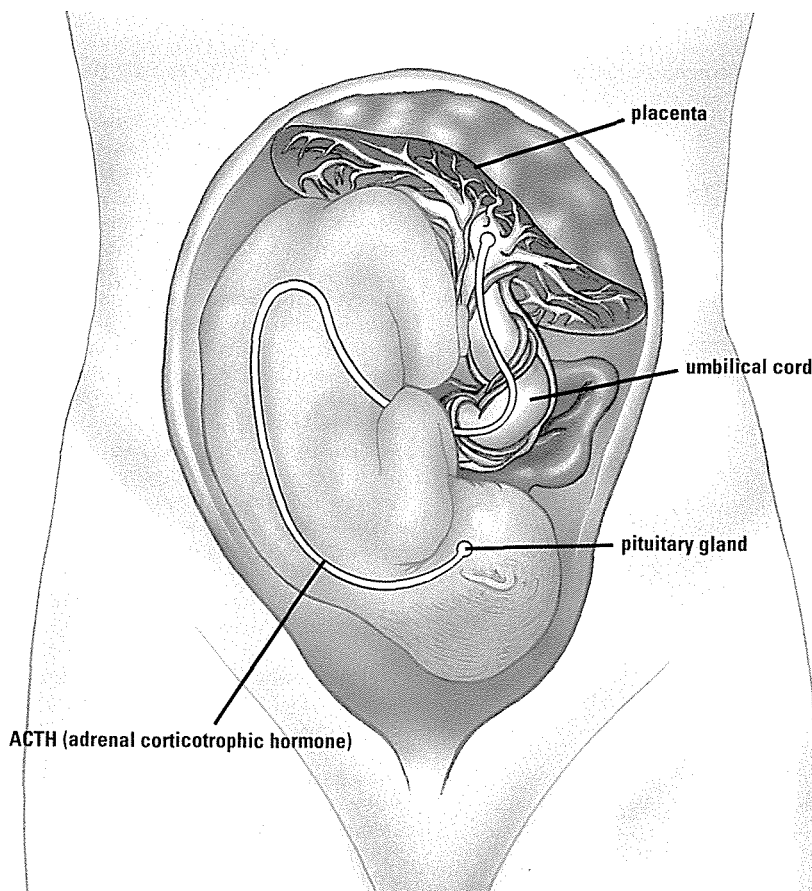
John Houghton

testosterone and is stored and made in the testes, the two little organs located in the human male's scrotum beneath the penis. In the female the equivalent hormone is oestrogen, the production centres for which are the ovaries – two little walnut-sized organs on the sides of the abdominal wall.

Men start producing sperm at puberty and continue up until about the age of 70. A single ejaculation contains about 300 million sperm, and in a lifetime millions upon millions are produced.

Before birth the female ovaries contain about 300,000 primary follicles (egg-producing sacs). With

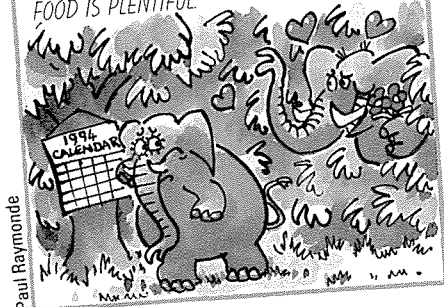
ACTH is the hormone, secreted by the pituitary gland of the baby, and sent via the umbilical cord to the mother, which starts the events that lead to birth.



Just amazing!

IT'S NOW OR NEVER

ELEPHANTS HAVE THE LONGEST PERIOD OF PREGNANCY OF ANY MAMMAL LIVING ON LAND – 22 MONTHS. THEIR CALVES ARE 'PLANNED' ALWAYS TO APPEAR IN THE SPRING WHEN THE WEATHER IS MILD AND FOOD IS PLENTIFUL.



pea-sized gland just beneath the brain, which secretes a hormone known as FSH. This goes to one of the ovaries where it causes a microscopic sac (called a Graafian follicle) to mature and migrate to the surface of the ovary. Inside the follicle is an immature egg. The FSH also stimulates the ovary to keep secreting another hormone called oestrogen. After 14 days, the build-

uterus, together with the unfertilized egg is expelled from the uterus in a process known as menstruation. It is at this point that the oestrogen comes into its own, helping to repair the wall of the uterus. For most women the whole cycle takes 28 days but stress, shock or illness can upset the hormonal balance and cause this to vary.

Conception

Menstruation only occurs if the egg is not fertilized. But if the egg is fertilized, it usually becomes implanted in the wall of the uterus and pregnancy results. When this happens, the Graafian follicle continues to produce progesterone. This, together with a steady flow of oestrogen from the ovaries, prepares the uterus for pregnancy, preventing menstruation.

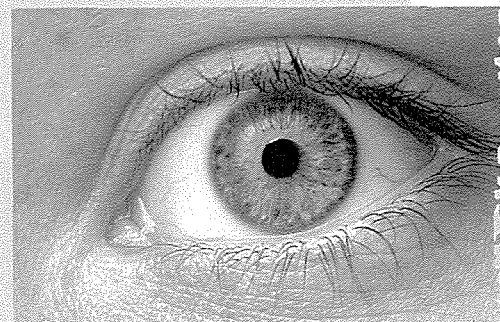
The progesterone also prevents further follicles from developing so that ovulation does not occur during pregnancy. As the placenta (the organ in the uterus that helps to nourish the foetus) grows, it takes over the role of producing progesterone and the Graafian follicle breaks down and wastes away.

Towards the end of the pregnancy (40 weeks or 9 months for humans) the level of progesterone decreases and that of oestrogen increases. It

is these changes that help to bring about the birth. Labour and its climax are the most dramatic examples of the controlling power of hormones.

However 'ready' a mother-to-be believes she is, it is the baby that actually sets the chain in motion. When it is ready – and many doctors believe that psychological fac-

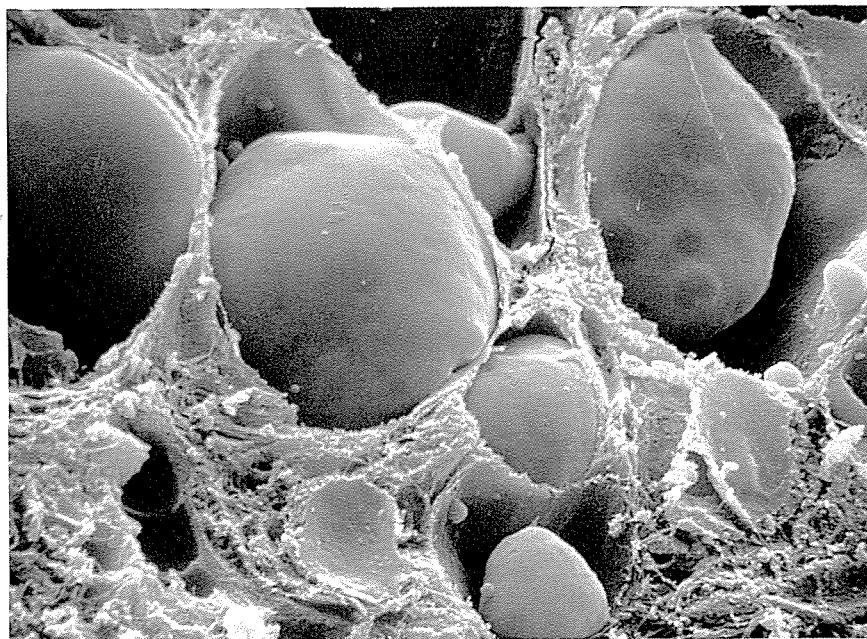
EYE SIGNALS



The first sign of sexual attraction are the eyes. As blood pressure rises, the pupils begin to open. In less than a fifth of a second they dilate, pulled by tiny muscles in the iris, from 2 mm in diameter to 8 or 9 mm.

At the same time, the eye itself moves rapidly after the subject of arousal, pulled by the six muscles in the eye socket. The blinking of the eyelid increases dramatically and the eyes are sprayed with a fine mist of tears, giving rise to the dewy-eyed gaze so often attributed to eager lovers. Women often emphasize their eyes with make-up to imitate this effect.

Martin Dohm/SPL



Manfred Kage/SPL

up of the oestrogen stimulates the pituitary to release another hormone called LH. LH induces the Graafian follicle to release the now mature egg. This is known as ovulation. After ovulation the Graafian follicle secretes yet another hormone called progesterone.

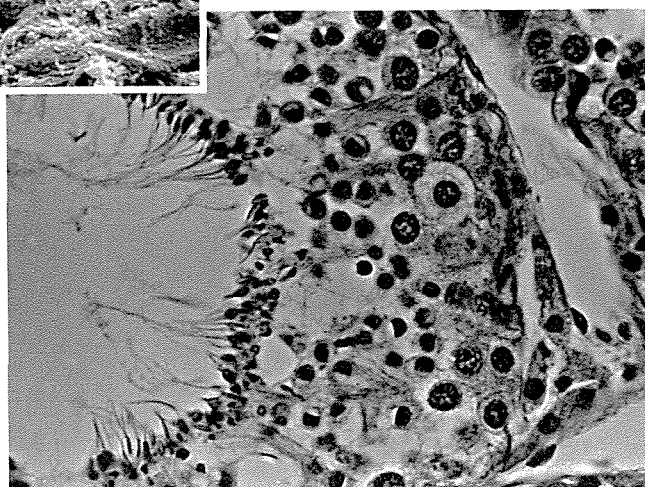
Progesterone prepares the uterine wall for implantation in case fertilization occurs and inhibits the production of FSH so that no more follicles develop. After a further 14 days the level of progesterone rises to a point at which the lining of the

A woman is born with half a million egg cells. Of these, only one per month develops to maturity in the ovary wall.

Sperm, in their millions, being produced in tiny tubes within a male's testes in a process known as spermatogenesis.

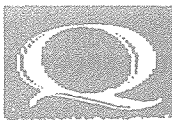
tors may be important – the baby releases a hormone called ACTH (adrenal corticotrophic hormone). ACTH stimulates the mother's tissues to synthesize a hormone called prostoglandin, a chemical that makes the uterus start contracting, heralding the onset of labour.

Then, as soon as he or she is born, the baby may go to the breast where a cocktail of antibodies, designed to fight infection, waits for the first, comforting, sucks of life.



Gene Cox/SPL





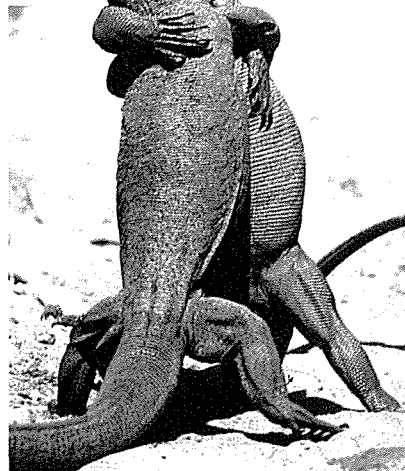
COURTING DISASTER

Charlie Ott/Bruce Coleman Ltd



The mating run of the Western Grebe, a native duck of California. Such behaviour is performed to stimulate the hen to become sexually receptive.

E Zingel/Frank Lane Picture Agency



Two male Bengal Monitor lizards engage in the species' fighting dance to establish dominance.

The Sea Cow, or Manatee, of the Atlantic tropical and subtropical coasts, engages in courting play.

The jaws of the Stag Beetle resemble antlers. Their only use is as a weapon against other males in their fight for first choice of mates.



Bugling is the term used to describe the ritual roar that a Red Deer stag performs. The loudness and frequency of the roar is linked to fighting success.

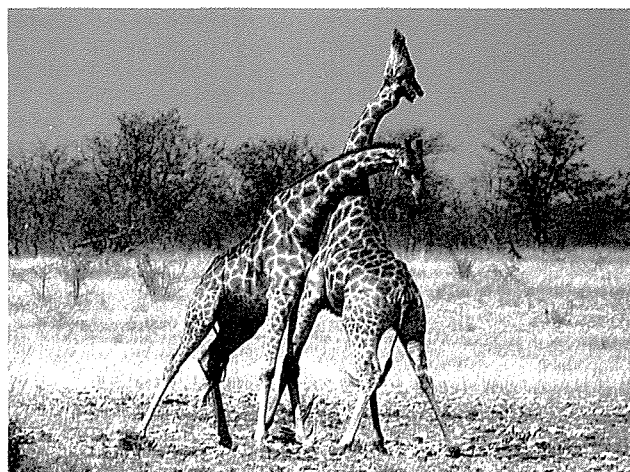
Manfred Danegger/NHPA



Francois Gohier/Ardea London



Stephen Dalton/NHPA



Clem Haagner/Ardea London

The Great Bower Bird of Australia and New Guinea is known for the ground nests or bowers, built by the male over several months, in order to attract a mate.



H & J Beste/Ardea London

Giraffes begin their courtship when the bull rubs necks with the cow in an action known as necking. A cow will mate with the dominant male in the area.



Many animals fight to establish a hierarchy among the males prior to mating. Bighorn sheep of the Rocky Mountains, USA, head butt to determine dominance. The highest ranking males have priority to the females as they come into heat.

Tom Ulrich/Oxford Scientific Films



BIOLOGICAL CLOCKS

The lunar day, from moon rise to moon rise, is 24.8 hours long. The moon pulls the sea towards it, causing two high tides a lunar day.

Many plants and animals in the sea and on the shoreline time their activities by the rhythms of the moon and tides.

regular and, necessary actions. The effect of their internal time sense can be observed, but how biological clocks work, or where they are located, cannot yet be fully explained.

External influences such as heat and cold, light and darkness, ensure that an animal's or plant's biological clock is set to the right time — that a particular activity continues to happen at a certain time of day. But in a laboratory, away from these outside stimuli, similar cycles of behaviour continue.

CAMOUFLAGE

TELLING THE TIME

THE HYPOTHALMUS

EATING, SLEEPING, HEADING south for the winter — these and many other vitally important, recurring activities in the natural world are timed by 'biological clocks' with remarkable precision.

Animals and plants have a natural sense of when to perform many

Tony Stone Photo Library, London



In their natural surroundings, earth worms, for example, need to stay below ground during the day to avoid the danger of drying out. They come up at night when the air is moist and cool. While they are below ground they cannot 'tell the time' by means of daylight or temperature. They need their internal — biological — clocks to tell them when to come up.

These biological clocks keep working even in a laboratory, where there is no day or night. Earthworms kept in glass jars of soil in a darkened room rise to the surface and become active once every 24 hours, then burrow down again to rest. Their cycle of activity keeps time with the unseen day and night

Some cacti flower as soon as daylight disappears and night falls. The flowers die before dawn. The Night Flowering Cactus, also known as Queen of the Night, comes from Mexico.

A polar bear's coat serves as camouflage. The fur will change from white to brown in the spring, when higher temperatures and longer daylight hours have melted the Arctic snow.



Peter Johnson/NHPA

emerge from its burrow in the sand near the water's edge — twice a day, at low tide. It scurries about, feeding, courting or mating, then buries itself before the tide comes in again. Kept in darkness in a laboratory at constant temperature, with no tides, it follows the same pattern of activity for weeks.

Internal clocks controlling annual changes are called 'circannual' — 'about a year'. Animals and plants adapt to a new season — the adaptations are started by changes in the temperature and the number of daylight hours.

Stags shed their antlers in the early spring and then start to grow new ones. The arctic hare, the arctic

outside in the open air.

Biological clocks most commonly have a 24-hour cycle. In a laboratory, rhythms of behaviour frequently continue over periods of time slightly longer or shorter than 24 hours. For this reason they are called 'circadian' — 'about a day'.

Plants also have circadian rhythms. The leaves of plants lift and droop, under the guidance of their internal clocks, to maximize the light they receive from the sun. The leaves of a bean plant kept in darkness also lift when the day outside begins and droop when it ends.

Circadian clocks

Flowers open so that they are ready at the time of day when it is most likely they will be visited by insects. They synchronize their opening with other plants of the same species, so that the insects can cross-pollinate them.

A plant's circadian rhythm can be altered by changes in temperature. The tropical African violet, for instance, grows best at a temperature of 20°C. At 10°C its cycle slows to 32 hours. In the wild it would die with a rhythm that was so badly mismatched with the length of the day. But kept in a laboratory with a

regulated 32-hour cycle of darkness and light, the plant flourishes at the lower temperature.

Many sea creatures have patterns of activity linked to the rhythms of the tides. Generally there are two high tides a day, separated by roughly 12½ hours.

The fiddler crab knows when to



The same butterfly produces different markings when it changes into a pupa in the spring.

The map butterfly *Araschnia levana* changes from a caterpillar to a pupa in the autumn prompted by the shortening day.



E J & J S Woolmer/Oxford Scientific Films



fox and the polar bear change their camouflage — turning white as the winter approaches and days shorten. Their coats darken with the coming of spring.

But when certain animals have been kept away from natural signals, such as changes in light and temperature, for periods of several years, they have continued these rhythms. Ground squirrels from the Rocky Mountains were kept indoors for three years. The temperature was maintained at just above freezing point and the length of their artificial days was always the same, so the squirrels did not receive the usual signals that winter was about to begin. Yet each October they began to hibernate as usual.

Out of sync

The squirrels' clocks, however, did run a little fast. Each year they hibernated slightly earlier than they would have in the wild. In laboratory conditions biological clocks always run a little fast or slow. Outside, daylight and temperature changes trigger alterations in behaviour and by doing so keep resetting the internal biological clocks so that they remain accurate.

The shortening day, as winter approaches, prompts many species

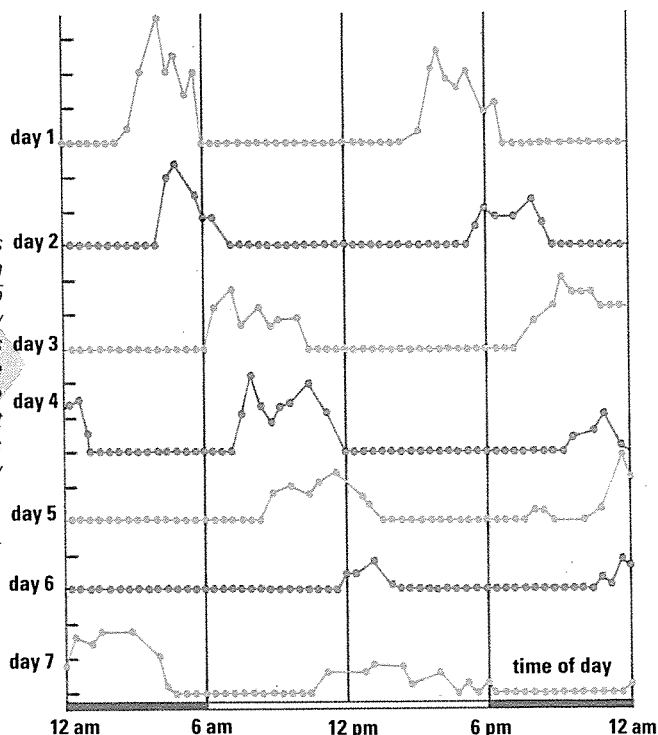


Frank Lane Picture Agency

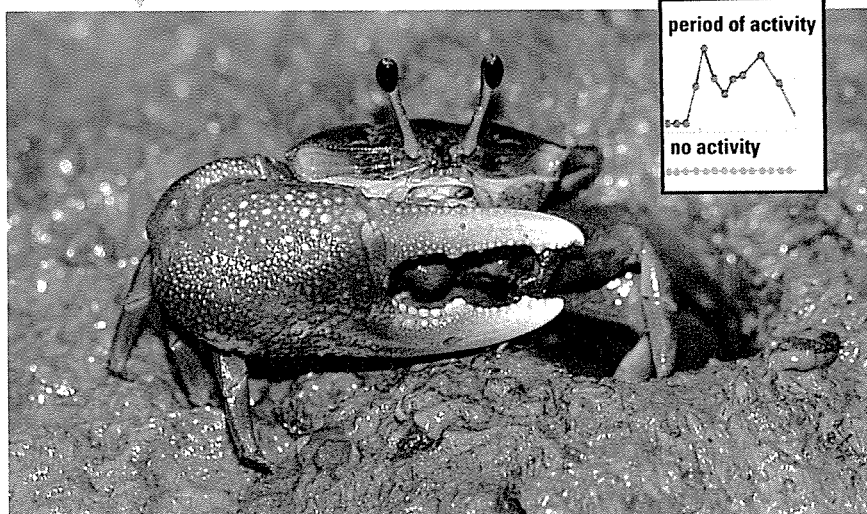
Cranes breed and summer in Scandinavia, before migrating to southern Spain and Portugal in October for the winter. They return to Scandinavia in March or April.

The fiddler crab has two bursts of activity in a lunar day (almost 25 hours). In a laboratory these periods continued, but the crab's cycle lengthened and got slightly out of sync with the times of low tides outside.

At low tide, fiddler crabs on the North American coast cram in all their activities before disappearing back into their burrows as the new tide comes in.



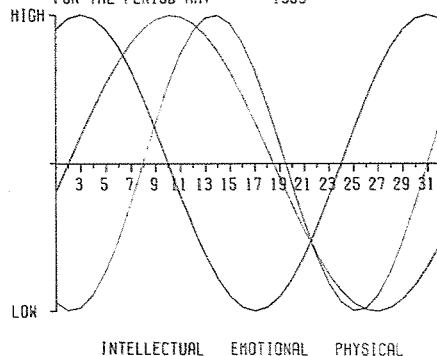
Caroline Brodie



Keith Scholey/Planet Earth Pictures

BIORHYTHMS

THE PERSONAL BIORHYTHM PLOT OF JULIA RUXTON
BORN 18/11/1959
FOR THE PERIOD MAY 1989



London Biorhythm Company

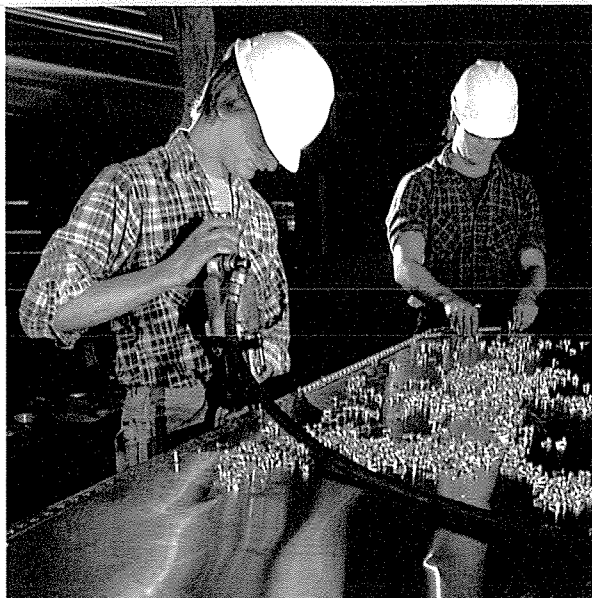
Many people say our moods, our thoughts and our state of health fluctuate in three different cycles, called 'biorhythms'. Biorhythms tick away at an unvarying rate from the moment of birth. We have an emotional 'high' every 28 days, while our body state varies in a 23-day cycle, and our mental condition in a 33-day one. When a cycle crosses the midline from high to low, or vice versa, that is a 'caution' or 'critical' day. On a caution day we may have an accident, be moody or make a bad decision. Scientific studies do not support the idea of biorhythms. If biorhythms do exist, they are the most amazingly precise biological clocks of all. In Japan they are taken very seriously — airline pilots are advised not to fly on their caution days.



of birds to migrate to the tropics. Just when warblers living in the wild are beginning their annual migration to the south, caged garden warblers become restless, too. A caged warbler lives in a room with artificial day and night, and yet it has an inbuilt urge to be off at this time of year.

The biological clock of a mammal, including a human being, seems to consist of a group of no more than a few thousand cells in a gland called the hypothalamus, just under the brain. These cells fire off electrical signals at a regular rate. (Such cells in rats' brains keep on 'ticking' even when removed and kept alive outside the animal.) The hypothalamus lies just above the point where the

Tony Stone Photo Library, London



Car workers on the night shift are not as efficient as they would be during the day – their internal body clocks will not fully adapt.

Leaves grow and fall from a beech tree, photographed in June, October and December. Changes are triggered by alterations in day length, temperature and light intensity.

Spectrum Colour Library



optic nerves from the eyes join – well placed to absorb information from the day and night cycle, which will keep the internal clock accurately set.

There are 'rhythms' – regularly occurring sequences of events – in the human body. The chemical composition of the blood and the urine changes throughout the 24 hours of the day. When scientists at Spitsbergen, inside the Arctic circle,

carried out their daily routines first by 21 hour 'days' and then by 27 hour cycles, the chemistry of their bodies stubbornly kept to a 24-hour circadian rhythm.

The menstrual cycle of women is a very important monthly cycle. Each month an egg is prepared for possible fertilization and the lining of the uterus is shed. The average length of the cycle is one lunar month (28 days), although it tends to vary slightly between one woman and another.

by the monotony, they would press the button much too often and overestimate the time they stayed in the 'black room'. They never did. Some of the volunteers made quite accurate estimates, but an equal number underestimated the passing of time wildly – one person thought he had been confined for 57 hours instead of 96.

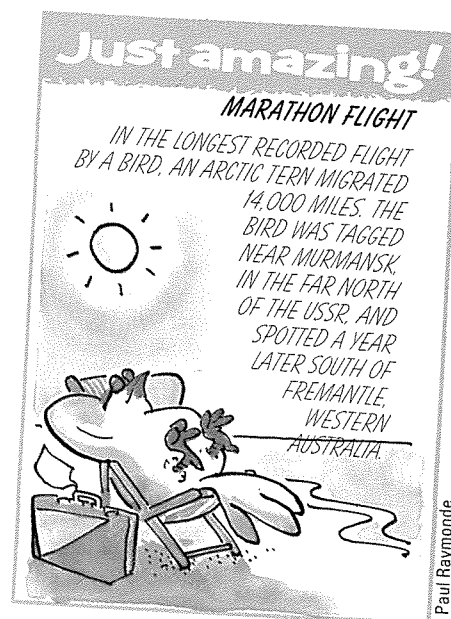
JET LAG

Leaving New York at 6 pm, you arrive in London at 6.30 am after a flight of seven and a half hours. London is five hours ahead of New York. Everyone in London is alert, ready to begin a new day. But the thought of activity of any kind fills you with horror – you feel tired, even ill. This is the condition known as jet lag. Your 24-hour body clock, which dictates the times for waking up, feeling hungry, going to sleep and so much else, is still set to New York time. A flight from New York needs a day's rest for recovery – double the distance, and you may need two and a half days to get your body clock 'in sync' with your new surroundings. There is no medicine for jet lag, except proper rest at the end of the flight.

Sense of timing

Our perception of how quickly time passes changes. To a child the day often seems longer than to an adult. One reason is that the heart of a human baby beats 140 times a minute, but an adult's heart beat has slowed to 70 a minute. The faster the heartbeat, the faster the pace of life, the more is crammed into the day and the longer the day seems to have been when you look back at it later.

Man is not very good at guessing how much time has passed. In an experiment, volunteers were kept isolated, in darkness and silence, for days at a time. Some were asked to press a button whenever they guessed that an hour had passed. You might expect that, being bored



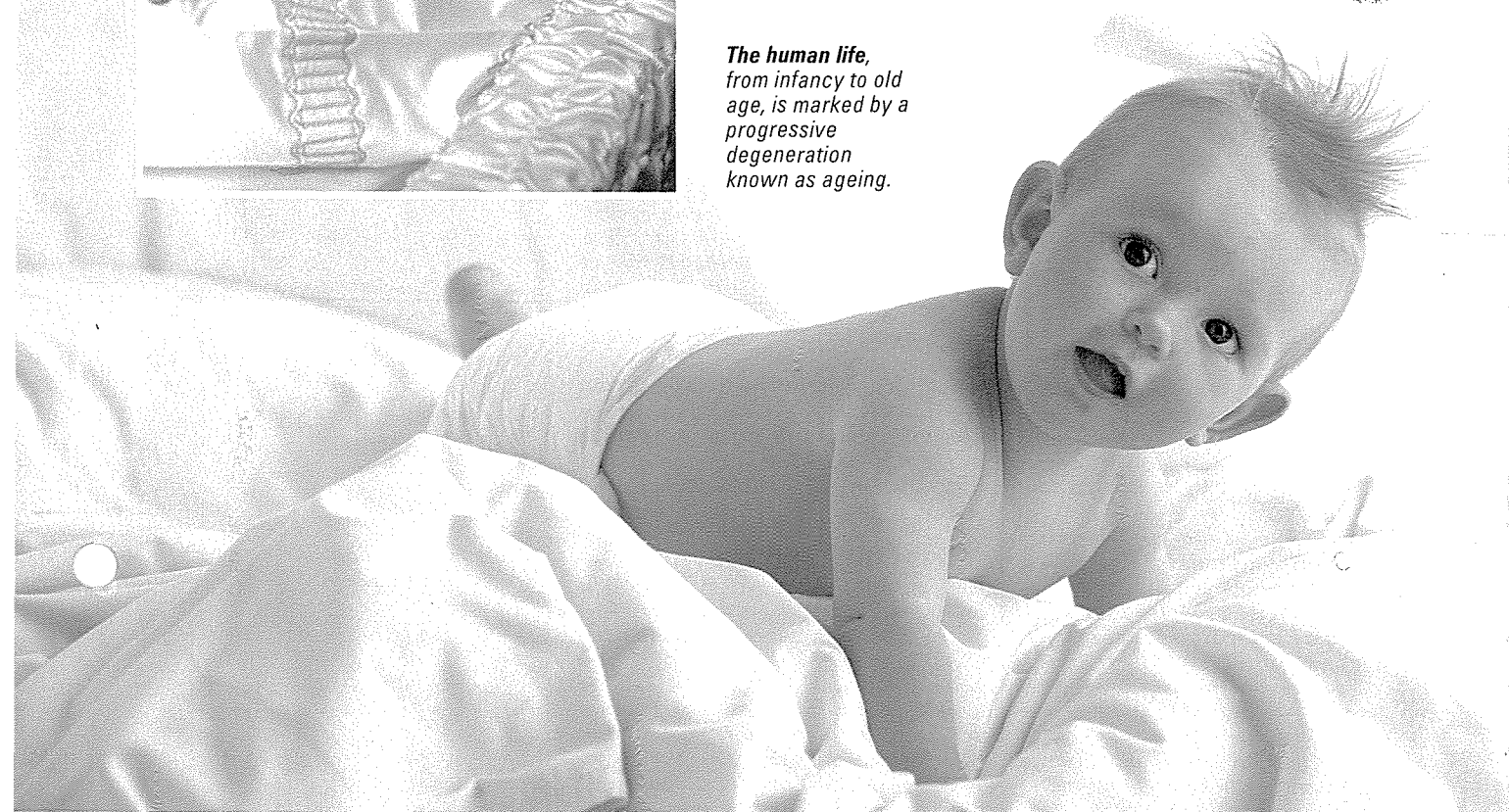
Paul Raymond





AGEING

The human life, from infancy to old age, is marked by a progressive degeneration known as ageing.



THE MAXIMUM HUMAN lifespan has not increased significantly since the Stone Age. Although average lifespans have increased dramatically in the last few hundred years, the maximum life expectancy remains at around 100 years.

Since the dawn of time Man has agonized over the meaning of life and death, but it is a biological fact that the evolution of species depends on the death of individual creatures. If a new generation, incorporating improvement, is to flourish, the previous generation must get out of the way. In other words, a species benefits if its members are 'programmed' to die.

Memory and thinking speed diminish with advancing age due to the withering of the dendrites, the long, limb-like links between nerve cells of the brain, and the death of the nerve cells themselves.

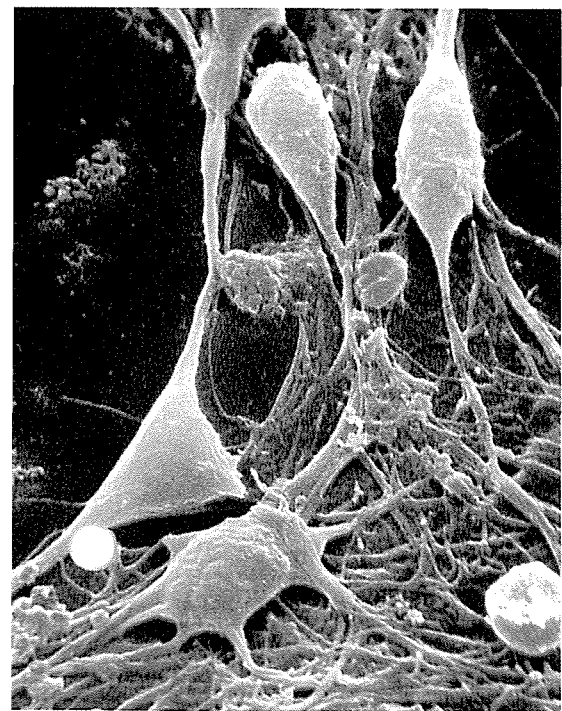
Many plants, for example, die immediately after they have scattered their seeds. Similarly, animals that reproduce only once in their lives, for example most insects, generally die immediately afterwards. Animals that breed repeatedly during their lives, larger mammals for instance, do not have such a sharply defined time of death, but they do deteriorate as they age.

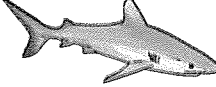
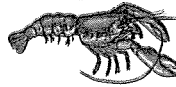
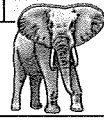


Deep roots

The oldest living thing alive on Earth today is an evergreen shrub called the box huckleberry, growing in Pennsylvania, USA. This single plant straggles along a slope by the River Juniata for more than 1½ km. It is reputed to be at least 13,000 years old.

Much younger is a bristlecone pine tree, growing high on a mountain in Nevada, at 4,600 years old. And some of the giant sequoia trees of California are estimated to be between 3,500 and 4,000 years old.



	house fly - 17 days
	starling - 17 months
	carp - 19 years
	shark - 25 years
	cat - 36 years
	lobster - 50 years
	elephant - 70 years
	man - 115 years

Caroline Brodie

Humans have a long life compared to most other animals. In general, the bigger an animal the longer it lives, but there are exceptions – the tarantula can reach 28 years and some deep sea clams have a recorded lifespan of 100 years.

Fransie Geringer, a 7-year-old who suffers from progeria, a rare disease which causes children to have the appearance of premature ageing. Sufferers rarely live beyond the age of 15–18, normally dying from heart failure.

Although on a cellular level ageing begins very early in life – for the brain, at least, at 7 years of age – most of its effects do not start to make themselves felt until much later in life. Of greatest significance are the following:

- The muscles of the heart deteriorate. Between the ages of 20 and 90 the amount of blood pumped by the heart decreases by 50 per cent. (Although the walls of the larger blood vessels thicken, so making the heart work harder, hardening of the arteries, called arteriosclerosis, is a disorder which can appear even in adolescents)
- Although the loss of teeth is

Nothing in the animal kingdom can match these lifespans. Giant tortoises have commonly lived up to 150 years. Lake sturgeon (a primitive fish) have probably lived to 100 years.

Human beings are long-lived by comparison with most animals. The longest definitely established human life was 120 years 237 days, achieved by a Japanese man named Shigechiyo Izumi.

It is wrong to think of ageing as an illness. Ageing is a process that goes on over the entire passage of an adult lifespan and is as much a part of living as infancy, childhood

and adolescence. The effects which are popularly associated with ageing, such as physical weakness or loss of mental ability, are in fact the effects of disease and not ageing itself.

Ageing theories

As people age, a number of changes occur within the body. These changes become visible both in appearance and behaviour. The ageing process starts on a cellular level and it is to the cells that scientists investigating ageing first turn their attention.

Cells are like chemical factories, manufacturing substances essential for themselves and the body. One theory of ageing, the mutation theory, is that chance errors build up over time. If the cell is one of those that reproduces itself, these errors will be passed on to the new cells and some errors will arise in the copying process. These errors build up until the cells cannot work properly.

According to another theory, the wear-and-tear theory, the waste products of body processes build up until cells can no longer work properly. Yet another theory, the auto-immunity control theory, holds that in old age the body's defence system (which attacks bacteria, viruses and poisons) goes wrong and starts to attack the body's own cells.

Alzheimer's disease, or senile dementia, results from the destruction of brain cells in old age as plaques – the pale area – are formed in the brain tissue. It causes forgetfulness and the inability to reason clearly.



Gamma/Frank Spooner Pictures

Just amazing!

DYING FOR A SMOKE

EACH CIGARETTE SHORTENS A SMOKER'S LIFE BY 5½ MINUTES ACCORDING TO AN ESTIMATE BY THE ROYAL COLLEGE OF PHYSICIANS IN LONDON, UK.



Paul Raymond



Hulda Crooks of California, USA was 91 in 1987 when she became the oldest woman to climb Japan's Mount Fuji. Since turning 65, she has climbed over 97 peaks above 1,600 metres.

A knee joint severely affected by osteoarthritis. The result of extreme wear and tear, it can cause great pain and hinder mobility.

this field have discovered that the biological make-up of a fit 60 year old is hardly different from that of a fit 30 year old. Correct diet, moderate exercise and not smoking will help to avoid diseases of the heart and lungs.

Similarly, the decline in mental powers among many old people is often made much worse by lack of stimulation. In many cases this can



CNR/Science Photo Library

more the result of long-term neglect than ageing, the overall process of digestion is not significantly impaired in the elderly

- From the middle 20s to the 50s there is a slight decline in *visual acuity* (the ability to see fine detail). Distant objects can ordinarily be seen more clearly than close ones with increasing age. Old age also sees a greater incidence of eye diseases such as glaucoma and cataracts
- *Hearing* changes little with age but over 50 there is a gradual reduction in the ability to hear high frequency tones
- After 70 there may be a reduction in *taste sensitivity* associated with loss of taste buds from the tongue. The *sense of smell* seems little affected
- *Reflexes* become increasingly

sluggish after 70

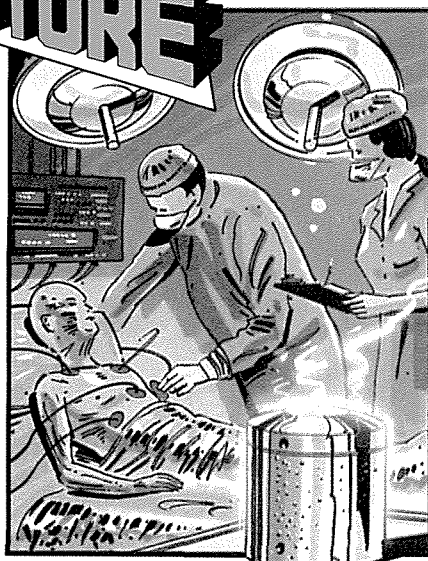
- The *skin* loses elasticity and wrinkles develop
- The *bones* lose calcium with ageing, becoming more fragile and therefore more likely to break. Healing is slower, the mobility of joints diminishes and the incidence of arthritis increases
- The efficiency of the *respiratory system* gradually diminishes as the bony cage of the chest stiffens, muscles lose their strength and the lungs themselves become less elastic
- *Physical capacity* is reduced in the elderly because of the inability to deliver enough oxygen to the working muscles
- *Short-term memory* worsens and response time lengthens with age.

The study of ageing is called gerontology and doctors specializing in

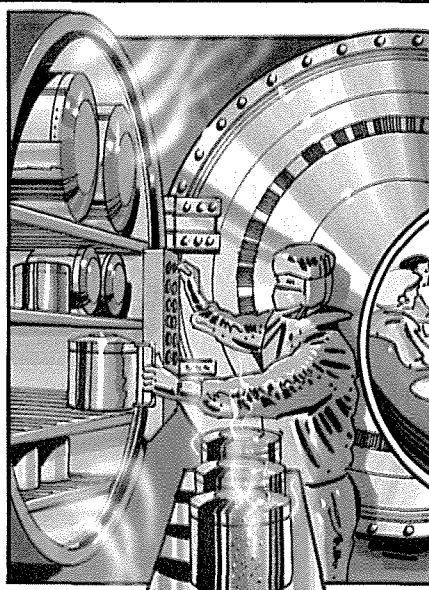
follow from loneliness, poverty and not having enough to do. Many people who 'age successfully' make conscious efforts to maintain mental alertness by continuing to learn and continuing to meet and talk to other people. Furthermore, older people who live independently in the community are more likely to be content and mentally alert than those living in old people's homes.

INTO THE FUTURE

FROZEN IN TIME



▲ Organizations in several countries now offer the chance of life after death. For a fee they will freeze the body – or just the head – of someone who has just died.



▲ The corpse will be kept in a vacuum flask for years – perhaps centuries – until medical science has learned how to restore the person to life.



▲ Eventually the remains will be brought back to life. If the head alone has been preserved, the rest of the body will have to be completely regenerated.

Joe Lawrence

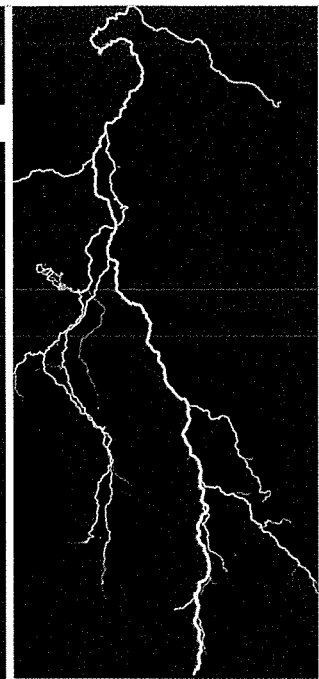




George Bernard Oxford Scientific Films

Insect lifespans vary greatly, from the few hours of a mayfly to the 20 or 30 years of the death watch beetle.

A lightning-bolt is simply a large spark discharging between a positive and negative charge.



David Parker/SPL

Subatomic particles, revealed by smashing bits of atoms into each other, exist for less than a ten millionth of a second.

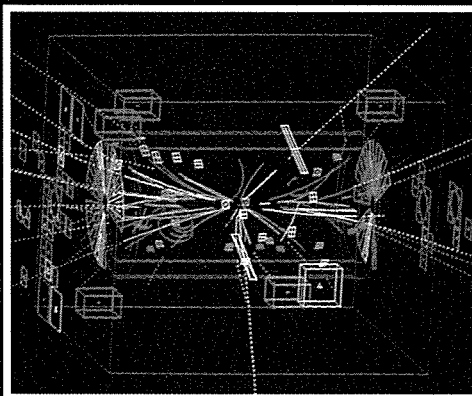


PHOTO CERN

The oldest living things on planet Earth include the giant sequoia trees of California, with ages estimated to be between 3,500 and 4,000 years old.



Eric Grave/SPL

The Rosette Nebula is a vast cloud of rotating gas several million years old, but its stars are less than 500,000 years old.

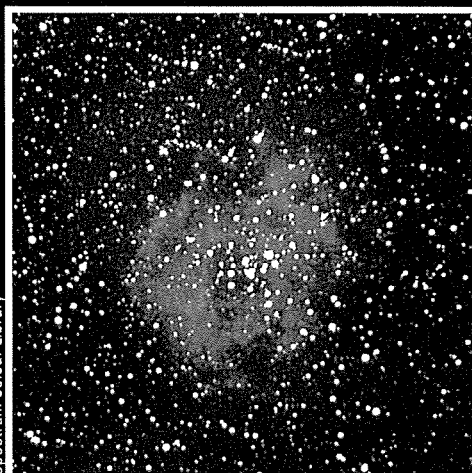


Spectrum Colour Library



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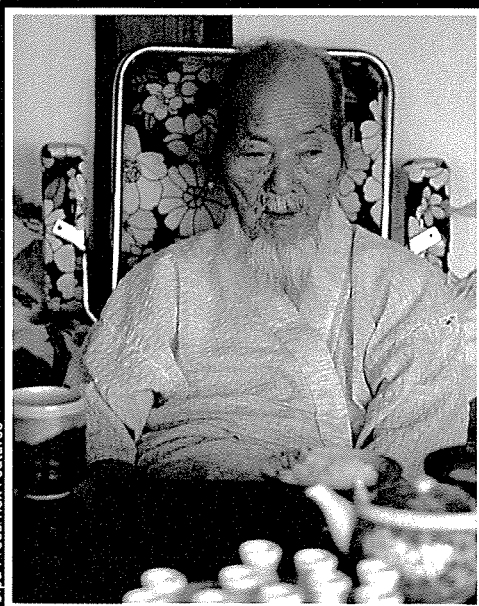
At 40 million years old, the Annapurna mountains in Nepal are youngsters compared with the Earth itself.



Spectrum Colour Library

The oldest recorded human life is that of Japan's Shigechiyo Izumi who reached an age of 120 years 237 days. He was born on 29 June 1865 and died, at home, on 21 February 1986.

A true immortal is the trumpet-shaped freshwater ciliate, a simple, single-celled animal. Its bell-shaped mouth is covered with hair-like filaments which beat, drawing in food particles.



Sipa Press/Rex Features



MICROSCOPIC

WATER

KILLER BACTERIA

MICROSCOPIC FOOD

STERILIZATION

EVEN THE CLEANEST NATURAL source of water is home to a vast range of microscopic plants and animals. These organisms are infinitely smaller and simpler than any aquatic predator but, in millions, they can be as deadly as a shark.

Water is a particularly efficient medium for spreading organisms

like those that cause gastrointestinal infections, such as cholera and typhoid. These diseases are caused by bacteria — tiny organisms that are visible only under the lens of an extremely powerful microscope.

Bacteria are single-celled organisms. Most are between 0.0005 and 0.002 mm long. They reproduce by binary fission — they divide in two, doubling rapidly. Given food and warmth, some can reproduce once every 20 minutes. When bacteria invade the body, they do so in millions — not singly — and the

The bacterium that causes cholera swims through water by wiggling its single 'flagellum' or thin, whip-like tail. In drinking water, it can kill.

doubling process soon leads to astonishingly large numbers.

Cholera is carried by a torpedo-shaped bacteria called *Vibrio cholerae*, and drinking water contaminated with human faeces is the main cause of infection. The cholera bacteria prevents the body absorbing salt. This causes diarrhoea, followed by vomiting, dehydration and even death.

Typhoid epidemic

Typhoid fever is caused by *Bacillus typhosus* — a rod-shaped bacteria with hair-like appendages. After infection, the bacteria incubates for up to 14 days. Symptoms include diarrhoea, nose bleeding and rose-coloured spots. After an attack, bacteria remaining in the intestine makes the victim a carrier of the disease.

Most water-borne diseases are as old as human civilization. But in 1976, a new disease struck in Phi-

Cholera's effects are swift and deadly. In areas of the world where sanitation is poor, bacteria in the faeces of victims gets into the water system, infecting more people and causing an epidemic.



Mark Edwards/Still Pictures



Philadelphia. Delegates at a convention of the American Legion were struck down with pneumonia-like symptoms.

Altogether, 34 people died in the outbreak. After an exhaustive search for clues, the bacteria that cause the disease were isolated and named *Legionella pneumophila*. The bacteria breed in air condition-

Kim Westerskov/Oxford Scientific Films

Many deaths have been caused by legionnaires' disease. Since it was first discovered in 1976, there have been several outbreaks around the world. In each case Legionella pneumophila have been discovered in the reservoirs of air conditioning systems or water storage tanks. Men are less resistant than women. Outbreaks in hospitals are especially dangerous.



Raw sewage pumped straight into the sea can be dangerous as well as unsightly. Cholera bacteria in human faeces (inset) can be filtered out by shellfish. Eaten uncooked, they re-infect humans.

Warren Williams/Planet Earth Pictures

vessels and gets into the liver, the results can be fatal.

Not all water-borne organisms pose a threat to human life. The amoeba and paramecium are two of the many harmless micro-organisms living in ponds, streams and generally moist environments. They, like many bacteria, feed on dead and decaying matter.

Ocean food

Plankton – a mixture of many tiny animals and plants – is found in the upper 100 metres of the oceans. The plants (called phytoplankton) convert sunlight and dissolved nutrients into food. Some of the animals (zooplankton) feed on them; others feed on the plant-eaters. Larger animals, such as fish, feed on the zooplankton, which is also a potential source of food for humans, too.

Water fleas, both freshwater and marine species, contain all the amino acids essential in the human diet. Up to 60 per cent of the dry weight of small crustaceans is protein. Tests are under way to farm phytoplankton and zooplankton to provide food.

Oxygen free

Not all bacteria require oxygen. One type is actually poisoned by it. These anaerobic ('without air') bacteria release oxygen-free compounds, such as methane.

The sulphur bacteria also live in conditions where oxygen is scarce or absent. Some species have been found in hot springs at temperatures approaching the boiling point

of water, where they feed on sulphur compounds.

Most harmful bacteria can be killed by boiling, however. In fact, heating water to just 63–66°C for 30 minutes, or 72°C for 15 minutes is enough. Where there is a real risk of contamination, however, water should be boiled. Another way to sterilize water is to add iodine or chlorine tablets.



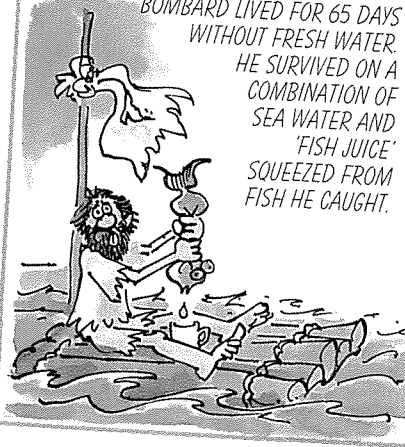
Water fleas eat microscopic organisms. They also contain all the protein humans need – but you'd need over a million to make up a fishfinger.

Geoscience Features Picture Library

Just amazing!

FISH AND SHIPS

ADRIFT IN THE ATLANTIC, DR ALAIN BOMBARD LIVED FOR 65 DAYS WITHOUT FRESH WATER. HE SURVIVED ON A COMBINATION OF SEA WATER AND 'FISH JUICE' SQUEEZED FROM FISH HE CAUGHT.



Paul Raymond

ing cooling tanks, and the disease is now known as legionnaire's disease.

Not all bacteria are harmful, however. Certain bacteria live in the human intestine and produce vitamin B12, important for general good health, and vitamin K, which helps blood to clot. Others are used to convert milk into cheese and yoghurt. Today, genetic engineers can grow specific types of bacteria to break down virtually any organic substance, including petroleum.

There are other small organisms called protozoans. Like bacteria, dangerous protozoans lurk in fresh water and moist soils, and they can be very harmful.

Entamoeba histolytica causes amoebic dysentery in humans. It is usually taken into the body in contaminated drinking water and causes serious ulcers in the intestine. But if it penetrates the blood



SELF DEFENCE



- FIGHT OR FLIGHT
- MARTIAL ARTS
- DEFENCE CLASSES

WHEN DANGER THREATENS, your body starts to change. Your heart beat rises. Adrenalin, the so-called 'fight or flight' hormone, is pumped into your system. More oxygen goes to your brain. You are preparing to run or fight.

The increased heartbeat makes your face redden, which is designed

to frighten off a potential attacker. In this excited state, you are better equipped to deal with danger than in a normal situation.

Personal security depends on the ability to run or fight when under attack. Many people feel that relying on their natural reflexes is not enough. They feel better prepared and more confident if they are

trained in some form of self-defence, notably one of the martial arts.

Martial arts harness these natural reactions to create a fighting capability of enormous power. But just as importantly, they instil a sense of discipline and restraint; true exponents only fight when they have to.

All the martial arts originate in the

Far East. One of the most popular forms is karate, which has been described as the 'ultimate art of unarmed combat'. Built around the basic techniques of punching, striking, kicking and blocking, karate aims to focus all the body's power in a particular move. You may have seen karate practitioners chop through bricks with their hands, or

These hands can kill! Karate is one of the deadliest forms of unarmed combat, and can be lethal if not practised properly. But exponents use their skills in competition only.





ZEFA

Giving bricks the elbow is simple for a karate expert. They can smash solid objects by concentrating all the body's energy into one small area.

break planks with a kick. These are really only party tricks that show how power and control can be developed.

● Holding back

'Free-sparring' competitions demonstrate how to land a blow on your opponent. As such blows can kill, the real skill is in stopping short of actually applying the blow.

Kung fu is a variant of the Chinese Chung-Kuo Chu'an (fist or hand) style of fighting. Like karate, it uses both the hands and the feet to attack an opponent. Kung fu has two sides to it; the 'external' and the 'internal'. The 'external' style is

all aggression while the 'internal' style gives the appearance of weakness. The idea is to lure the opponent into striking, then turn the power of the attack back on to him. As in karate, the true kung-fu practitioner is happiest when he knows he has the skills but does not use them, except as exercise for the mind and body.

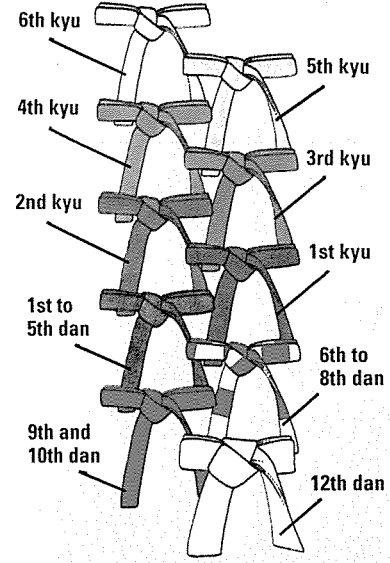
● Forbidden moves

Judo or ju-jitsu comprises four basic skills: how to fall when thrown, how to throw an opponent, how to apply arm locks and strangle holds and how to pin an opponent to the ground. A fifth skill, which involved striking at an opponent's weak spots such as the eyes and groin, used to be taught but is no longer in use.

Aikido, which translates as 'martial spiritual harmony', was developed in Japan during the 19th century in an attempt to create the ultimate fusion between the physical body and the spiritual mind. Like judo, it uses the force of the attack for its own power – the opponent's strength is used to defeat him.

There are other forms of martial arts that are not designed to help in an everyday situation, such as kendo, which uses armour and weapons. Likewise, there are other forms of self-defence that are not

JUDO GRADES

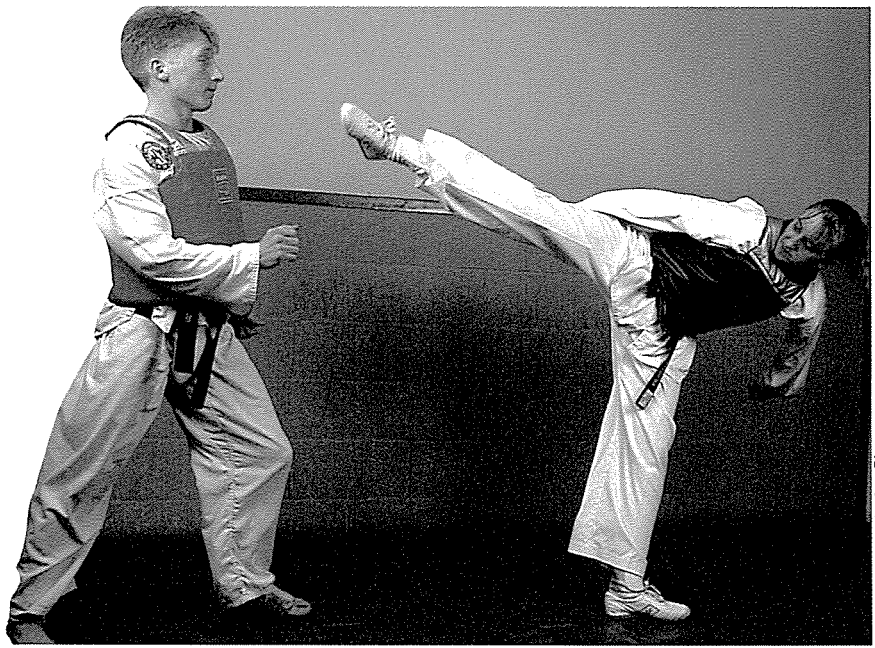


Caroline Brodie

In judo, the skill of a practitioner is signified by belts divided into kyu (pupil) and dan (degree) sections. A beginner (6th kyu) wears a white belt with the fighting costume, and progresses by examination.

Above the 5th Dan, the awards are made on the basis of a 'master's' contribution to the development of the art rather than merely fighting skill.

Only one man has ever reached 12th Dan – Dr Kano, judo's founder.



Richard Francis/Action Plus

Just amazing!

BULLY-BOY

KOREAN KARATE CHAMPION MAS OYAMA WAS FAMOUS FOR HIS EXHIBITIONS. HE ONCE SMASHED 30 ROOF TILES WITH A SINGLE BLOW AND HE DEFEATED 52 BULLS IN COMBAT KILLING THREE.

Paul Raymonde

classified as true martial arts. These are purely designed to help someone defend themselves against an attacker, and might involve spitting, poking, butting, stamping – activities generally frowned upon by martial arts' practitioners.

As cases of violent crime rise, self-defence classes are becoming popular. Most local authorities offer classes to women, who may be afraid to travel on their own after dark. They are designed to boost the woman's confidence as well as

Taekwondo can be practised by men and women equally. It is an excellent way of combining sport, fitness and a form of self-defence.

give her the knowledge to protect herself from potential attackers.

It must be stressed that martial arts can be extremely dangerous if practised by the untrained. If you want to practise any of the skills, join a class or club with approved instructors.



NERVE IMPULSES

EAR DISEASES

ECHO LOCATION

HEARING SEEMS LIKE THE easiest, most natural thing in the world — in fact it is a fantastically complex business. Your ears can both detect the faint buzzing of a bee and analyse the roar of a jet engine a million million million times louder.

Sound travels to us through the air as *compression waves*. The ear picks up these waves and sends detailed information about them to the brain. It is then that we are aware of the sound. The nerve connections from the

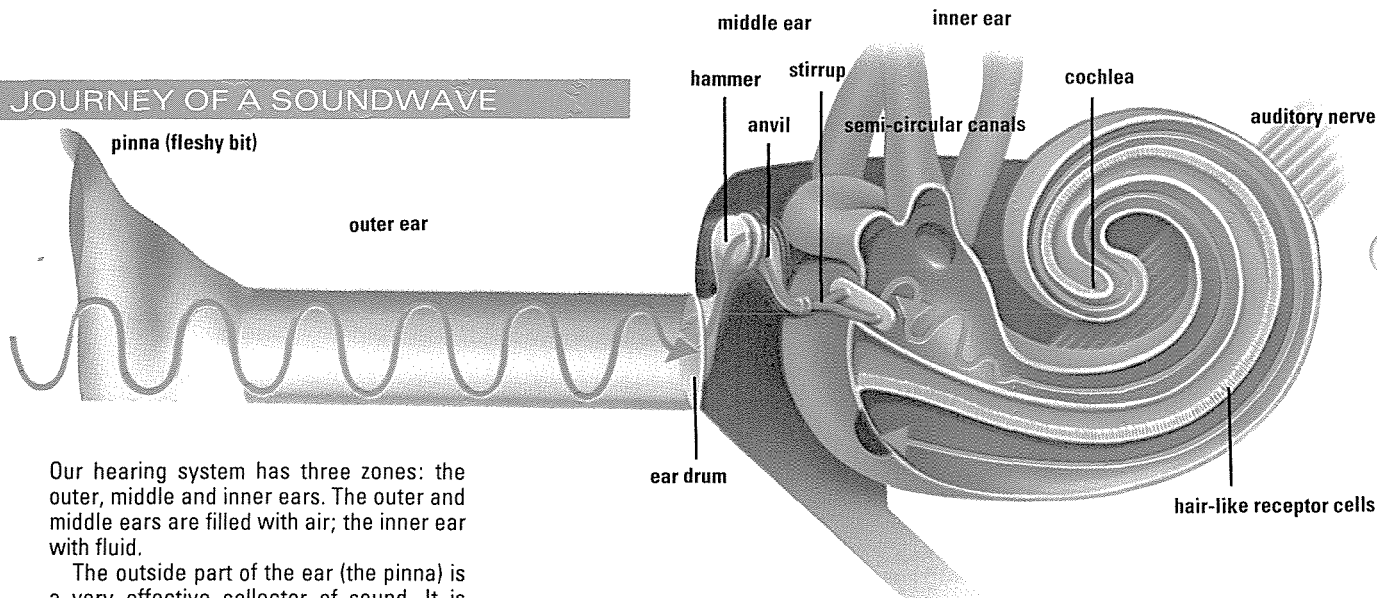
ZEEA

David Redfern

TUNING IN - HOW WE HEAR



JOURNEY OF A SOUNDWAVE



Our hearing system has three zones: the outer, middle and inner ears. The outer and middle ears are filled with air; the inner ear with fluid.

The outside part of the ear (the pinna) is a very effective collector of sound. It is important in particular for helping us understand which direction sound is coming from. The pinna channels the sound down the auditory canal into your ear – towards the middle ear – where the sound waves strike the ear-drum. This is a membrane which forms a barrier between the outer and middle ears.

Like the skin of a drum, the membrane vibrates when sound waves hit it. These vibrations are transmitted across the air-

filled middle ear to the inner ear by the three smallest bones in the body – the hammer, anvil and stirrup. These act together as a mini amplifier.

The inner ear is made up of a series of canals which control our balance. They are known as the semi-circular canals.

Another three canals, coiled in the shape of a snail's shell, are called the cochlea.

The stirrup is connected to the inner ear

at a thin membrane called the oval window. Movement of this causes waves in the fluid in the canals. These waves are detected by over 20,000 tiny hairs on the inside of the cochlea. The movement of these hairs stimulates nerve cells at their base.

Signals from the nerve cells go down the auditory nerve to the brain, where they are interpreted – and we hear the sound.

Advertising Arts

SH & DH Cavanaugh/Robert Harding Picture Library



A personal stereo puts you in a world of your own – but high volume at such close quarters can damage your hearing by killing the tiny hairs in your inner ear that detect sound.

Massive volumes of sound are required to fill Wembley Stadium. Those at the front can literally feel the compression waves from the heavy bass notes being absorbed deep in their chests.

party effect'. However, if certain words – your name in particular – occur in the rejected background sound, your attention immediately switches to it.

In the 'civilized' world it is accepted that hearing deteriorates

ears to the brain are crossed. Sounds in the right ear are mainly handled by the left side of the brain, while sounds in the left ear are handled by the right side.

The two sides of the brain seem to specialize in different types of sound. When different words are put through the two earpieces of a pair of headphones at the same time, words going in the right ear are more easily unscrambled. The opposite is true of music – music going into the left ear is heard more distinctly. So scientists believe that the left side of the brain is responsible for analysing language, and the right side music.

Attention

Concentration is another factor in hearing. You can hear the sound of a quiet conversation that you are interested in over loud background noises – this is called the 'cocktail

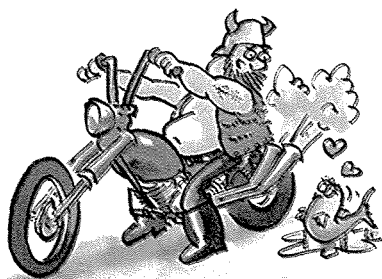


as you grow older. The small bones of the middle ear become progressively less mobile and the hairs of the inner ear die off. But tests of certain African tribes show no hearing loss among the elders. A study of 500 Mabaan tribesmen showed that nearly all of them, regardless of age, could hear a whisper over the length of a football pitch. Perhaps our noisy Western world – full of

Just amazing!

VROOM, VROOM

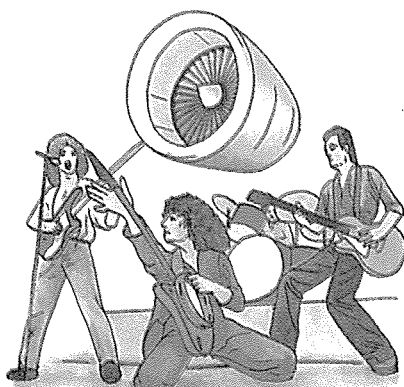
FISH MAKE NOISES TO ATTRACT A MATE. MINNOWS PURR. COD GRUNT. WHILE THE LOVE SONG OF THE HADDOCK SOUNDS LIKE A MOTORBIKE.



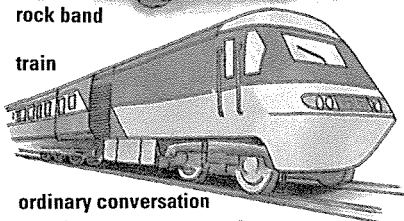
Paul Raymond



jet engine idling



rock band

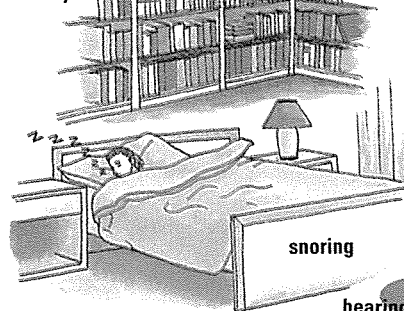


train

ordinary conversation



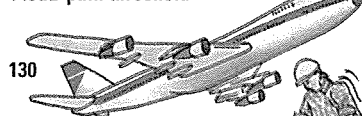
library



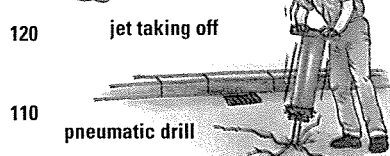
snoring

hearing threshold

140dB pain threshold



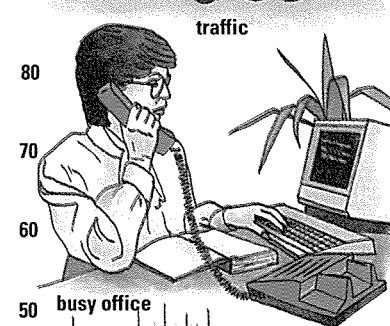
jet taking off



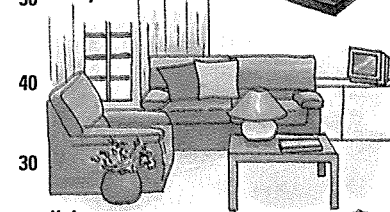
pneumatic drill



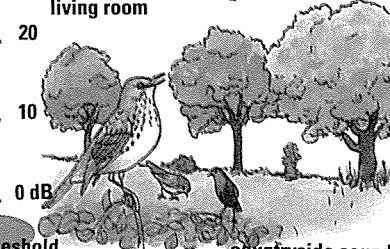
traffic



busy office



living room



countryside sounds

The decibel (dB) scale is not a straight forward measure of sound intensity. Doubling sound intensity does not double the dB. It adds just over 3 dB to the measurement.

In music, blindness is no handicap, as singer and multi-instrumentalist Stevie Wonder proves. The blind have to 'see' with their ears, so their hearing becomes exceptionally acute.

the sounds of cars, radios, aeroplanes and building sites — causes the progressive loss of hearing.

Insects can hear, too. Even the blowfly has receptors in the joints of its antenna that can detect sound. Nocturnal moths have membranes on either side of their bodies connected to receptor cells. Using these, they can detect the ultrasonic cries of hunting bats and turn themselves to make the smallest possible target. Male mosquitoes have their hearing finely tuned to sounds between 150 and 550 Hz, the wing tone of the female.

TUNING IN — HOW WE HEAR

Fish do not need an outer and middle ear. Since fish tissues are about the same density as water they can detect the sound vibrations directly in the inner ear. Some fish have a gas-filled bladder connected by bones to the inner ear which acts as a kind of eardrum.

Most reptiles have their eardrums on the outside of their bodies, but birds, like humans, have their eardrums inside their heads connected to the surface by a canal.

Night sight

The barn owl uses its extraordinary hearing to capture mice even in total darkness. Its ears are placed at slightly different angles — its right ear is turned slightly upwards, the



Stephen Dalton/NHPA

The highly developed hearing of the mouse-eared bat means that it can catch its prey even in pitch blackness. Echoes of the ultrasonic squeaks it emits are detected by its direction-sensitive ears, so it can locate even the smallest flying insect.

left slightly down. By comparing the sounds in its two ears, it can fix its prey's position precisely. It can even determine the direction in which a mouse is moving, in order to fasten its talons along the line of the mouse's body.

Shrews, oilbirds and the Himalayan cave swiftlet 'see' in the dark using echo location. They emit high-pitch sounds and detect objects from their echoes. Dolphins use a more advanced form of echo location, but it is bats that have perfected it.

Flying prey

Bats emit pulses of ultrasonic sound — outside the range of human hearing. That way they are not confused by the low-frequency sounds made by the wind and other natural phenomena. Again, the echoes tell them where things are.

Insect-eating bats have large external ears which are particularly sensitive. It is able to capture very small flying insects at the rate of two per second.

Caroline Brodie

Gamma/Frank Spooner Pictures



Robert Harding Picture Library

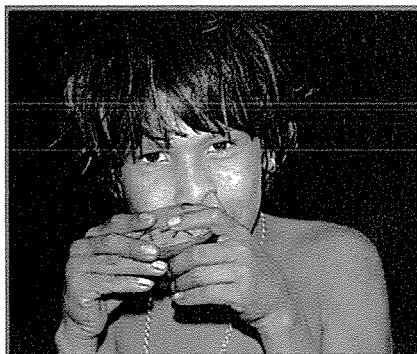


Simple resonating pipes are blown by Brazilian Indian during the coming-of-age rites of Xingu Kuarup. The pitch of the note depends on the length of the pipe. The players here can produce two notes each.

The din's the thing at the Junkanoo festival on New Providence Island in the Bahamas. Providing it in abundance are drums, whistles, home-made horns, bells and rattles.

An eccentric Englishman strikes a low note with a length of piping amplified by an ordinary lavatory bowl – showing that almost anything will make a noise if blown, banged or plucked.

Jesco von Puttkamer/Hutchison Library



The nose flute is played by Amazonian Indians. One nostril is closed with the thumb – the flute is blown with the other.

Tony Stone Photo Library, London



Musical monks in the Thikse Monastery at Ladakh, Tibet praise God by blowing on their sonorous Tibetan horns and banging large drums.

Tony Stone Photo Library, London

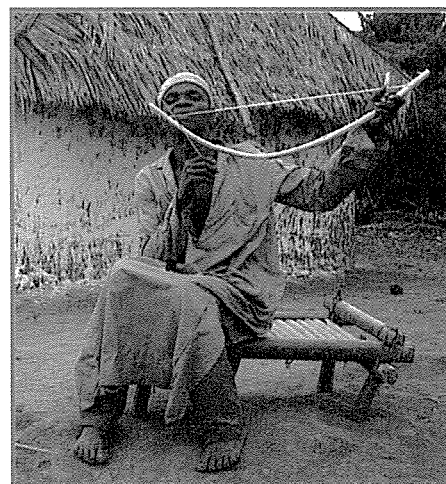


A kongon or mouthbow being played at Tapari in the Cameroons. The mouth is used as the sound box to amplify the note produced by the string.



The gangsa or metalloghphone is the principal instrument of a gamelan (percussion) orchestra from Bali. Similar in principle to the wooden xylophone, its metal strips are struck by a metal hammer.

JG Fuller/Hutchison Library



V & A Wilkinson/Hutchison Library

P Moszynski/Hutchison Library



The harp is usually associated with Wales or Ireland. This South American version is being played in the Andes by a Quechua Indian, a descendant of the Incas.

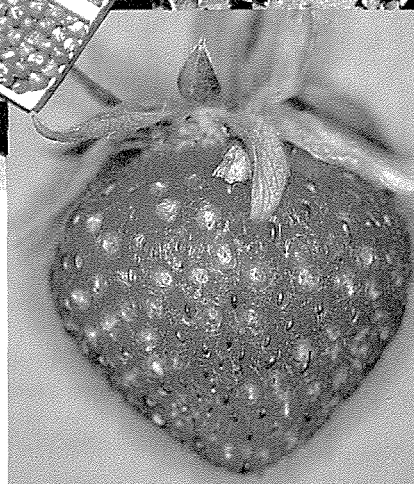


Hutchison Library



Driscoll Strawberry Associates

PEST



The Bug-Vac was invented in California to combat the lygus bug, which lives on the top leaves of the strawberry plant. A huge vacuum cleaner on wheels, the Vac sucks up the bugs.

Crown copyright/Brogdale EHS

CONTROL

CHEMICAL POISONS

FARMERS ARE PLAGUED with pests that attack their crops and livestock. The pressure to get crop yields as high as possible and to rear large, healthy livestock has never been so great.

THE BUG-VAC

It is estimated that, even today, 30 per cent of possible world food production is lost to diseases, pests and weeds before harvesting and another 15 per cent is lost between being harvested and reaching the consumer.

IMMUNIZATION

Pesticides are chemical mixes put together by scientists that kill pests, be they insect, worm, weed or fungus. They are usually sprayed on to crops; animals can be sprayed or bathed in water in which the pesticide has been dissolved. Insecticides have a crucial role in the fight against insect-borne diseases, such as malaria, which affect man as well as other animals. Without pesticides cereal yields would drop by up to a quarter in the first year.

New pesticides

Enormous sums of money are spent on developing and testing new pesticides. As many as 10,000 new chemical compounds have to be tested to produce just one new pesticide. This process takes seven years or longer and may have cost up to £30,000,000 by the time the new pesticide is in the farmer's

WAR AGAINST PESTS

Name	Acts against
Pesticide	Any 'pest' – anything that causes disease or poor growth in humans, pets, or farm animals and crops
Insecticide	Insects such as beetles, caterpillars, grubs, locusts, fleas and flies
Acaricide	Mites and ticks, often infesting cattle and sheep
Nematocide	Roundworms; thread worms; nematodes
Rodenticide	Rodents, such as mice, voles and rats
Molluscicide	Molluscs, such as slugs and snails
Herbicide	Weeds – plants growing where they are not wanted
Fungicide	Fungi, such as plant mildews and rusts; also moulds



MAN-MADE PEST

In an attempt to fight the beetles that were devastating the sugar-cane crop in Queensland, Australia, over 30,000 cane toads were imported from Hawaii, in the hope they would eat the insects. Unfortunately, the sugar-cane fields were too hot and dry for the toads – they spread into the surrounding bush and ate the native insects instead by the tonne. Cane toads are themselves poisonous if eaten and have caused the death of many animals (including dogs) that tried them for supper. The toads have now spread across much of eastern Australia.



Z Leszczynski/Oxford Scientific Films

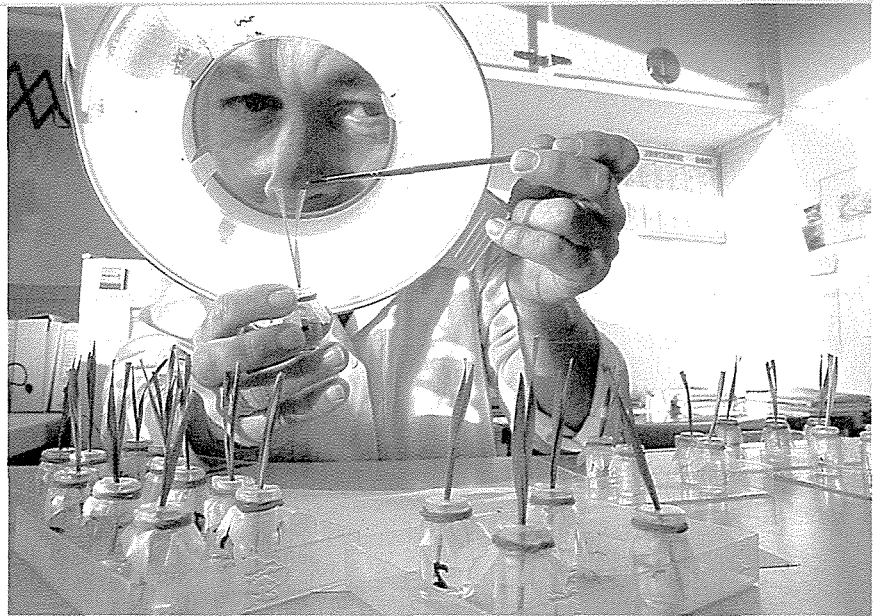
sprayer. Up to half this sum is spent on testing for poisonous effects on other forms of life and on how the chemical will behave when it gets into the environment – the soil, water and air.

But the big pesticide companies cannot measure and check every aspect of the long term effects of their products. When chemical pesticides are sprayed on the land there may be unwanted, dangerous side-effects. Pesticides contaminate the soil. Rain washes the soil and any pesticide chemicals it contains into streams, which run into rivers and lakes eventually contaminating the sea.

The food chain

Plants absorb some chemical pesticides either from direct contact or together with nutrients from the soil or water. Animals eat affected plants and may be, in turn, eaten themselves by bigger animals – such as ourselves. Thus the whole 'food chain' is polluted. Residues of DDT (an insecticide now widely banned) have even been found in Antarctic seals and penguins.

Chemicals that make up pesticides do not easily break down into harmless substances – the amount in a plant or animal slowly builds up as more and more of the chemical is



Viard/Jerrican

absorbed. These chemicals are poisonous, and can even kill.

The USA alone manufactures \$800,000,000 worth of pesticides each year and sells 40 per cent abroad. The use of DDT was banned in the USA in 1972 – yet American companies still make 18,000,000 kg of this chemical each year for export, mainly to poor nations.

Often such pesticides are used without proper precautions by farm workers with outdated equipment who cannot understand the instructions, which are usually printed in English. At the same time, some farmers deliberately ignore the instructions and warnings printed by

In an experiment, a scientist looks through a magnifying glass lit by electric light so that he can see the wheat seedlings on which he is painting a new pesticide.

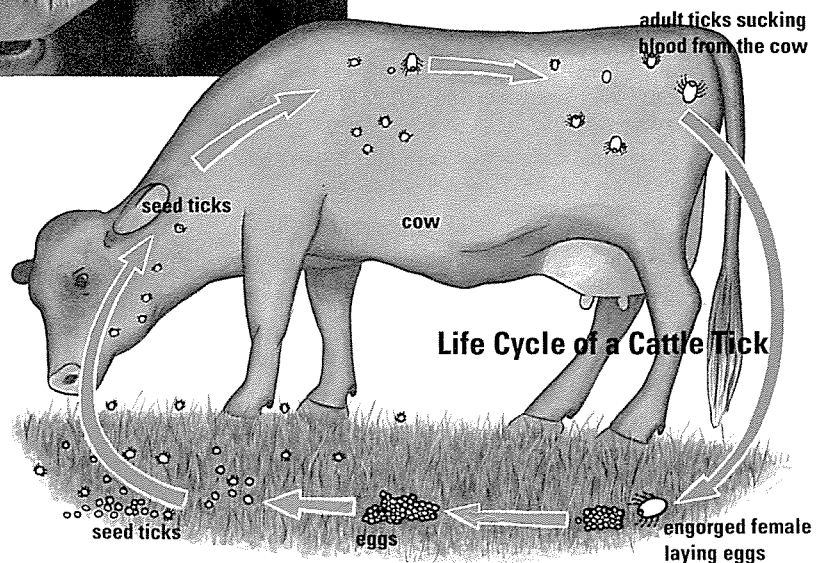
the manufacturers on the packaging.

Pesticides are, in general, used more carefully today than in the past because of our increased awareness of their side-effects. Some particularly poisonous pesticides have been banned – but the pests they attacked have still to be dealt with.

There has been a population explosion among the locusts in North Africa due to higher-than-average rainfall in the Western Sahara. Some experts in the region are calling for the return of dieldrin, a banned pesticide, to control the

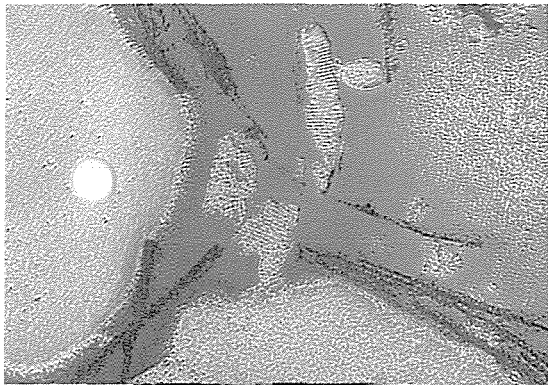


The eggs of a cattle tick hatch into 'seed ticks', which swarm up grass blades and attach themselves to a cow – a favourite place is the inside of the ear. Once adult, the size of a matchhead, a female feeds for about a week. Engorged, she drops off the cow, lays up to 3,000 eggs and dies.



John Houghton



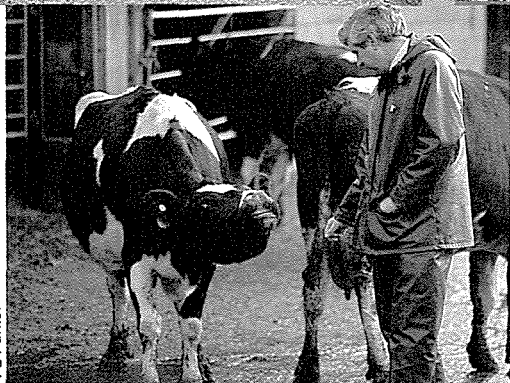


EM Unit, CVL, Weybridge/SPL



PEST CONTROL

David Jackson



PE Parker

A new disease, Bovine Spongiform Encephalopathy, has attacked 5000 cattle in Great Britain since the first case in 1986. The virus, which affects the brain, makes the cow go mad and destroys its muscular co-ordination (left). The disease was transmitted to cows from sheep; its name comes from the spongy nature of infected brain tissue (top left). All infected cows are slaughtered and burned (top).

mounted on a tractor that sucks over four strawberry rows at once. The lygus bugs are the main ones to be sucked up and 'blow-killed' as they pass through a fan at a speed of 30 miles an hour.

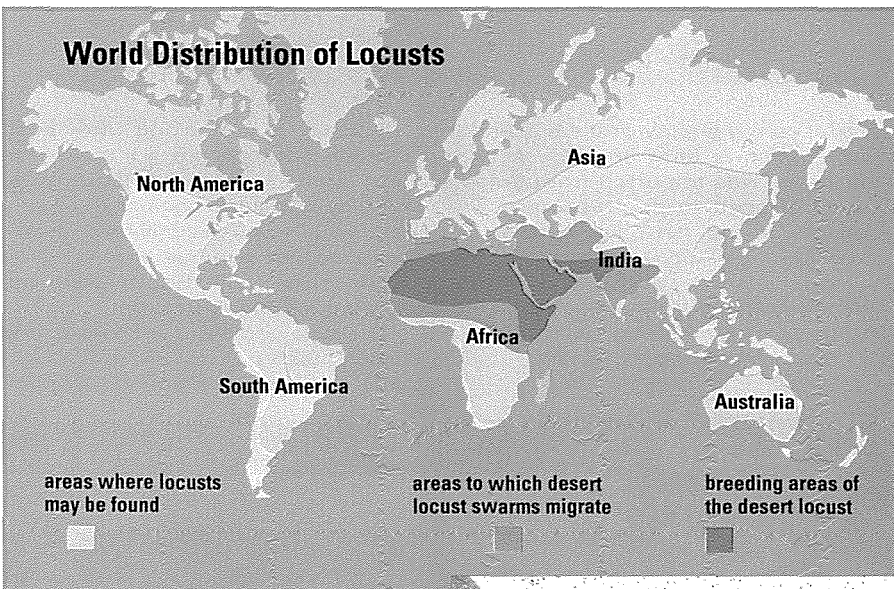
It might seem more sensible to exploit 'natural' poisons, instead of using 'unnatural' man-made ones. Spiders prey on insects, disabling and killing them with their poison fangs. Studies of the Japanese joro spider and European agriope have revealed the chemical structure of

A locust swarm will eat everything that is green, stripping the countryside bare (inset lower right). The biggest swarm of desert locusts on record covered an area of 5,000 square km and contained about 250 billion locusts.

swarms and stop them spreading.

Immature locusts, called hoppers, do not have wings so they cannot move far. If a strip of land is sprayed with dieldrin, it will form a barrier that the immature locusts cannot cross, because the dieldrin will kill them. Fenitrothion, another pesticide, has been used but it quickly breaks down in the soil (thus doing less long-term damage) and so makes a

World Distribution of Locusts

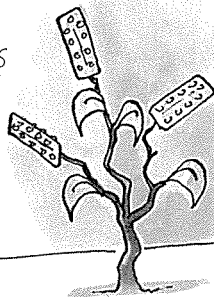


Jeremy Banks

Just amazing!

PLANTS FIGHT BACK

A PLANT IN THE NEGEV DESERT, ISRAEL, PRODUCES A CHEMICAL WITH THE SAME EFFECT AS THE BIRTH CONTROL PILL – IT REDUCES THE BIRTH RATE OF THE COWS, SHEEP, GOATS AND RATS THAT EAT IT.



Paul Raymond

less effective barrier. The swarms that have escaped the fenitrothion will produce huge future generations of locusts.

Sometimes machines can do the work of chemicals. In California, strawberry farmers now use great vacuum-cleaners to suck pest bugs off their crops. Strawberry pests include the lygus bug in the upper leaves, the western flower thrip in the lower leaves and the two-spotted spider mite on the underside of leaves.

Hoovering crops

This last pest is so resistant to pesticides that the huge amounts needed to kill it would wipe out all the 'good' creatures that prey on the pests and keep the numbers under some sort of control. Enter the 'Bug-Vac', a four-part hoover



Gamma/Frank Spooner Pictures

their poisons, which act as nerve paralyzers. If the chemical could be slightly modified, it might be suitable as a short-acting insecticide that breaks down naturally.

However, it is also possible that if this insecticide were to be used on a huge commercial scale, some insects could develop an immunity



to it and, therefore, to the poison of the spiders themselves. Since spiders kill and eat many more insects than the farmer could spray, this is obviously undesirable.

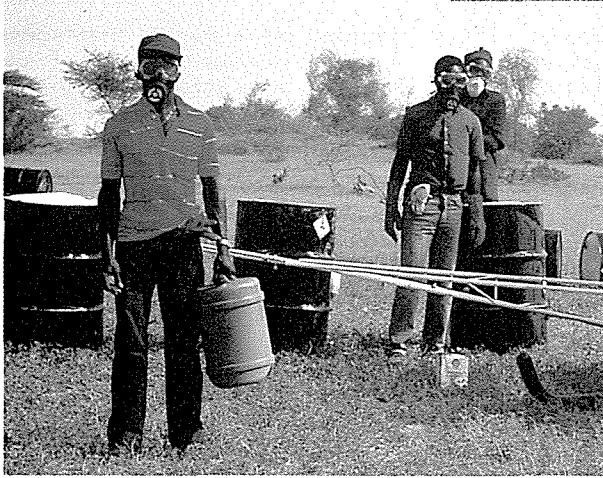
Instead of using an animal's poison, how about using an animal itself to control pests? 'Biological control' has been tried many times around the world – with mixed success.

A purple-flowering weed called Paterson's curse has spread over large areas of Australia. The weed



Tony Stone Photo Library, London

Gamma/Frank Spooner Pictures



Pesticides can be used in a number of forms including granules, dusts and fumigants, but the majority are diluted in water and applied as sprays. Aerial spraying (above) is not very efficient – only 30 per cent of the spray lands on target.

in 8000 times its own body weight in blood from the host. Milk production is affected, the cow's hide is damaged and diseases are spread from animal to animal.

Jabs for cattle

In a series of experiments (each involving picking out up to 60,000 ticks from infested cattle with tweezers) scientists identified the substance that made some cattle naturally resistant to the tick. This was used as the basis of a vaccine, with which a cow is inoculated.

When a tick sucks blood from a vaccinated or naturally resistant cow, antibodies in the animal's blood destroy the tick's gut. The damaged tick drops off its host and dies. Once the vaccine gets into full production cattle ranchers should be able to use less anti-tick pesticide spray.

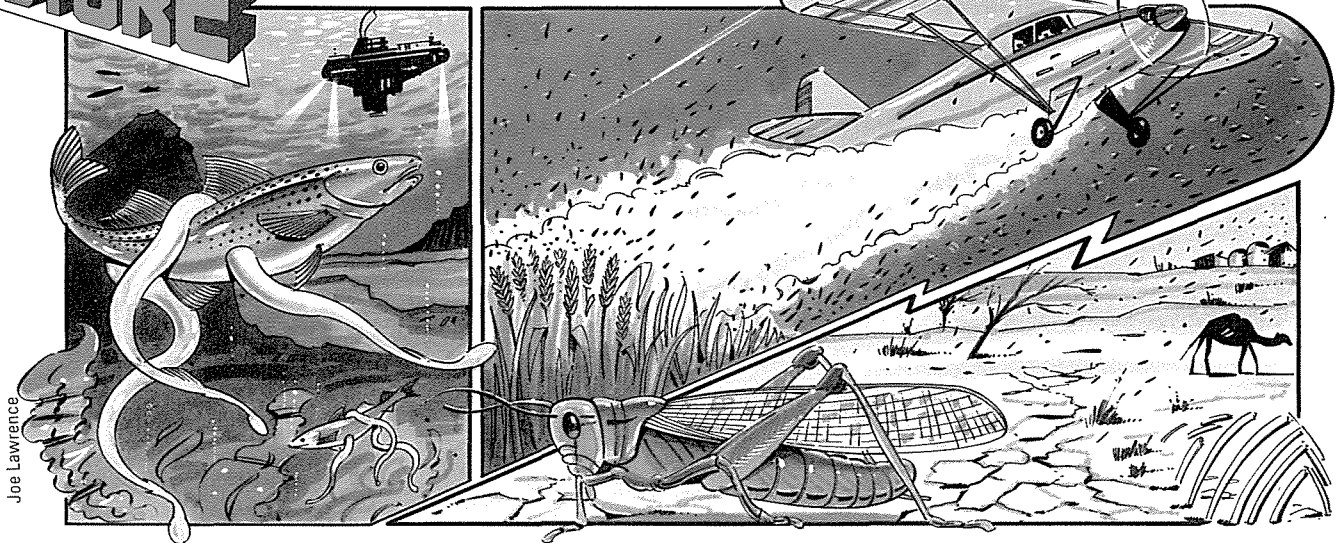
reduces the quality of the soil and it also poisons farm animals. A type of moth was imported from France and released in south-eastern Australia in the hope its caterpillars would eat their way through the weeds' leaves and kill the plants. Whether this will be successful, and without side-effects, will not be known for a number of years.

Instead of attacking the pest, another approach is to make the farm animal or plant resistant to it. In 1988 a vaccine against the cattle tick, which causes millions of dollars worth of damage among herds in Australia and South America, was produced in Australia.

The tick, a distant relative of the spider, fastens its sharp mouthparts on to an animal and can suck

INTO THE FUTURE

SUPER-PLAGUES



Joe Lawrence

▲ As fish we eat become sick in polluted seas there could be a plague of hagfish – a predator that preys on weak, diseased fish – creating a desert in the oceans.

▲ On land, pesticides will have to be used in ever greater strengths and ever greater quantities in order to deal with pests that mutate to obtain immunity.

▲ Eventually, the lack of a safe, effective weapon could mean a devastating plague of locusts, laying waste to whole areas of previously fertile land.



THE BODY'S DEFENCES

KILLER PARASITES

TYPES OF GERMS

Sneezing, captured on a special shadow photograph, sprays millions of bacteria that can pass on infection in the air.



Malcolm Fielding, Johnson Matthey plc/SPL

GERMS POSE A CONSTANT threat that we must guard against. The body is equipped with a very powerful defence system – the immune system. It is a collection of cells – the white blood cells – programmed with the special tasks of seeking out and destroying germs.

Germs are a group of organisms that cause disease. This group is split into bacteria, viruses, fungi, protozoa and parasites.

There are thousands of different types of bacteria, but they all share one basic feature – they can only be seen under a microscope. Some need very high-power magnification

Protective clothing and air-tight visors are worn to prevent researchers coming into contact with germs.

to become visible.

Each bacterium (singular for bacteria) is made up of a single cell, less than 0.01 mm in diameter – about 16 times thinner than a human hair.

● **Fast breeders**

Bacteria are of four basic shapes and they are named accordingly: they may be spherical (coccus), rod-shaped (bacillus), curved rod shape (vibrio) or spiral (spirillum).

Bacteria have a remarkable rate of reproduction. In perfect conditions,

one bacterium can produce 1,000,000 copies of itself in 7 hours. In practice this rarely happens because their food is insufficient.

● **The good, the bad . . .**

Bacteria live all over our bodies and are very important to health (especially in the gut where they make vitamin K which is important in blood clotting). Not all bacteria are good for health, of course, but there is a balance in the number of both types. If this balance alters (for example, if you don't brush your teeth, and harmful bacteria are allowed to outnumber the good bacteria) then disease occurs – in

GERM WARFARE

Dr Gary Settles/SPL

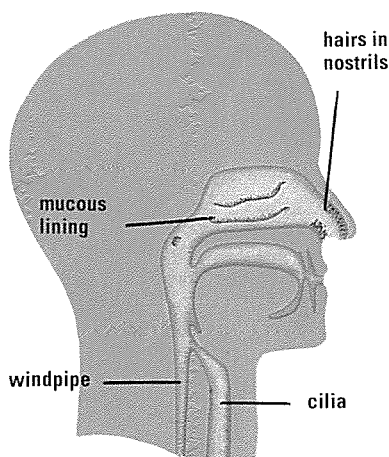


this case caries, or tooth decay.

Viruses can only be seen through an electron microscope. The smallest virus is 0.00001 mm long – about 16,000 times less than the diameter of a human hair.

Double lives

Viruses can exist in either a living or a non-living state. When outside their host (the organism they live in) they are crystals and can live for any length of time in this state – they can even survive in space. Once inside the host, however, they become active and start to invade the host's body cells. They take over

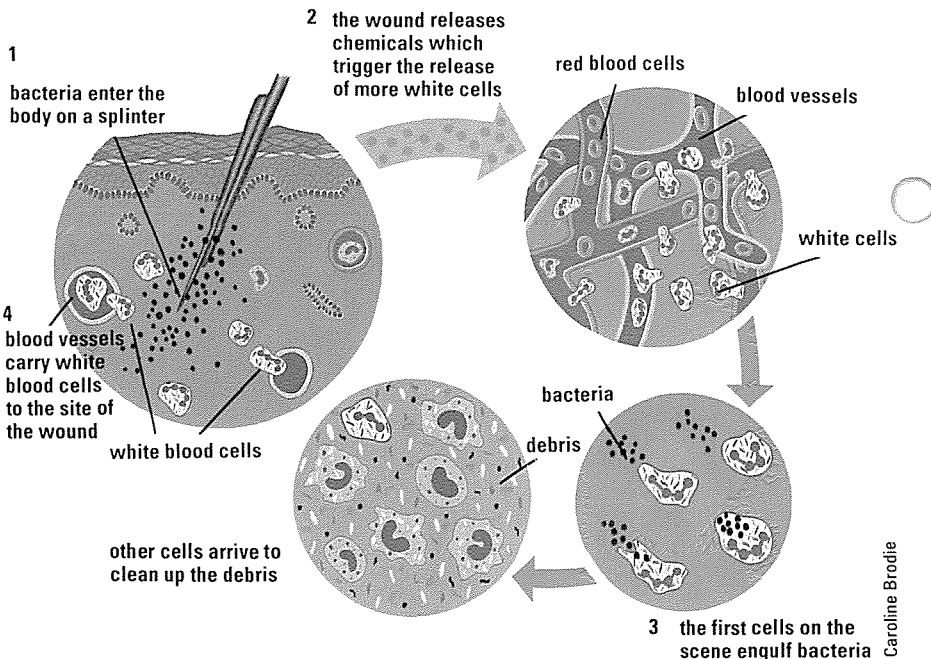


Caroline Brodie

The nose and mouth are lined with mucus and cilia (hair-like tissue), both of which trap germs that are inhaled.

the cell's life functions for their own use and reproduce until the cell dies. The new viruses are then released to infect other cells, and the cycle is repeated. This is the reason viral infections progress so quickly and that patients can fall ill so suddenly.

The common cold is a typical viral infection. It starts with sneezing, headaches and joint and muscle

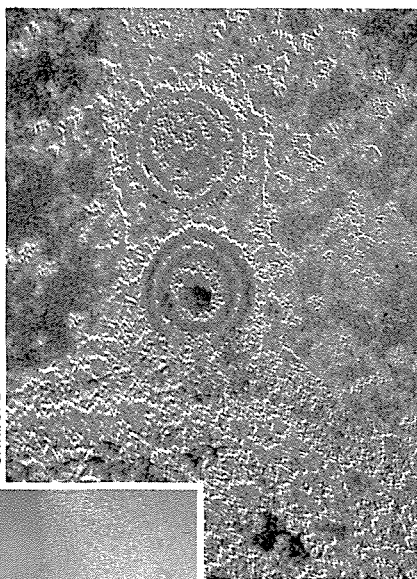


Caroline Brodie

pains. Once the body starts producing mucus in the nose and throat, then other bacteria begin to thrive. The cold then starts to become runny and the mucus turns green due to the bacteria living in it – this is called a secondary bacterial infection, a common complication.

Other viral infections include polio, chickenpox and measles in humans; foot-and-mouth in cattle, distemper in dogs and myxomatosis in rabbits. Certain viruses are

Bacteria entering the skin on a splinter alert the body's defences (1). Chemical messages from the wound travel through the blood and cause white blood cells to rush to the site (2). The first white cells on the scene engulf the bacteria and are killed along with the bacteria they engulf (3). Other white cells arrive and clean up the debris (4).



CNRI/SPL

Cold sores are small blisters caused by the herpes virus (above). Virus particles (orange) move from the nucleus (green) to the surrounding fluid (blue) of a cell they have infected. The blisters are unsightly, but not life-threatening.

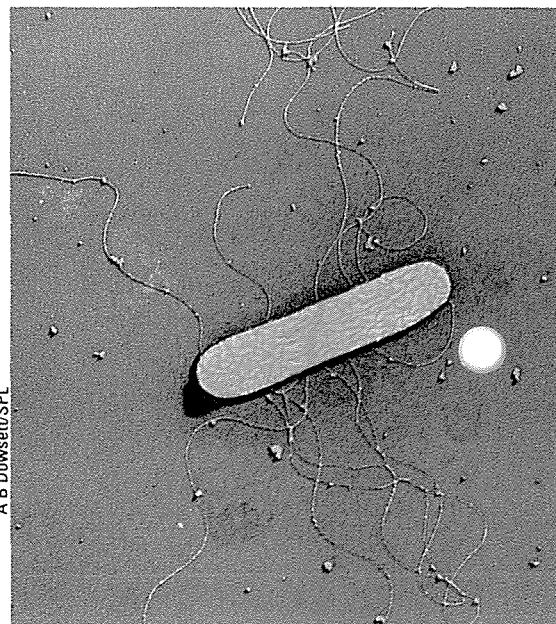
linked with the development of cancer.

The damp, moist conditions that favour bacterial growth also encourage the growth of fungi.

Itchy feet

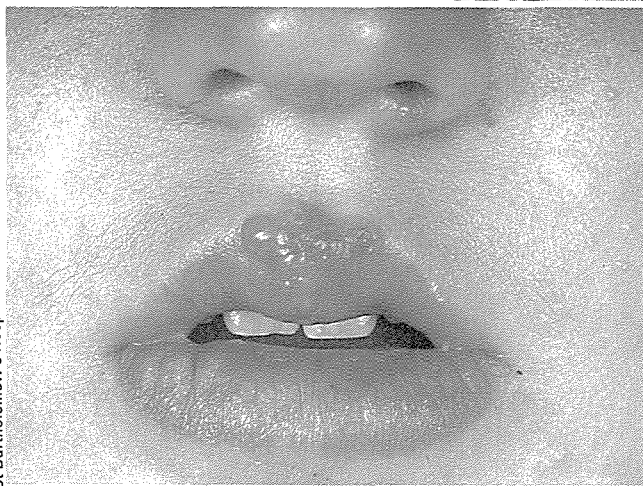
A good example of fungal infection is athlete's foot – seen between the toes as a white, scaly rash which is very itchy. The same type of itchy rash can occur on the head and

Listeria bacteria cause food poisoning; the bacteria grow well in food that is not kept cold enough.



A B Dowsett/SPL

St Bartholomew's Hospital/SPL



AIDS – WHEN THE BODY LOSES ITS DEFENCES



Lawrence Migdale/SPL

Our immune system is very effective in its action, but it can break down. The best known example of a break down in the immune system is AIDS (Acquired Immune Deficiency Syndrome). The cause of AIDS is not fully understood, but it is believed to be a virus (below left). This virus enters the cell and alters its functions in such a way that it becomes confused. The infected cell does not recognize the body's tissue as 'friendly', and so attacks it as it would a germ.

At present there is no cure for AIDS, so the most important thing is to prevent the spread of infection in the first place. AIDS can enter the body only via the blood or during sexual intercourse. Intra-venous drug abuse carries a high risk. People should never inject themselves, unless they have a medical reason (for example if they are diabetic). Doctors advise the use of a condom during sexual intercourse, and the fewer sexual partners the better. AIDS takes about six months to develop to the stage where it can be detected.

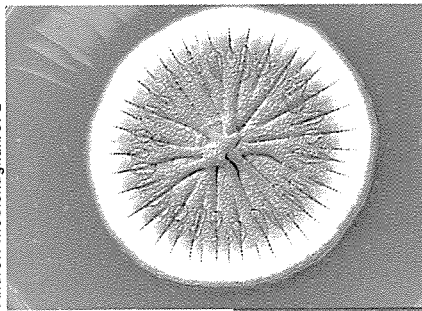
Prof Luc Montagnier, Institut Pasteur/CNRI/SPL

body, where it is called ringworm. Minor conditions such as these are easily treated, but prevention (in this case keeping your body clean and dry) is the best practice.

Dirty water

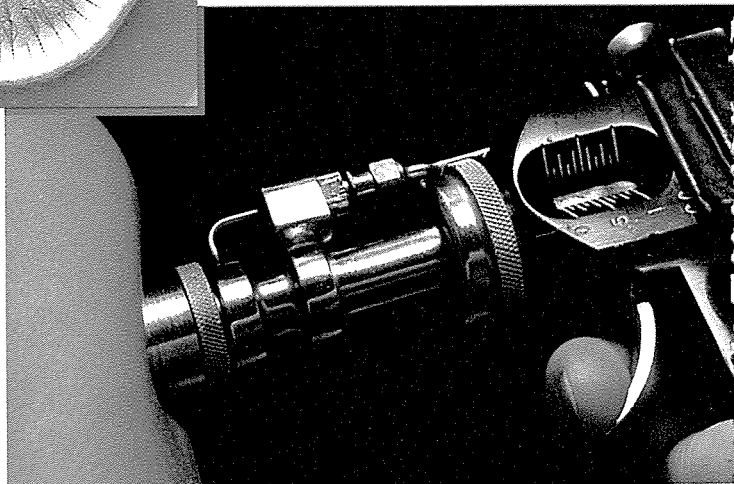
Protozoa are the simplest organisms in the animal kingdom. In many developing countries, where water hygiene is often poor, they cause much illness because they thrive in unpurified water. Protozoa are unicellular (they are made of one cell) and range greatly in size from microscopic (0.005 mm) to the size you can actually see.

The amoeba is a protozoan commonly found in ponds or slow-running streams. When water in-



Andrew McClenaghan/SPL

A gun device is used to spray accurate doses of vaccination through the skin. The dose helps the body to fight diseases. Penicillin, produced by the penicillium mould (above), is an antibiotic that acts against bacteria.



Just amazing!

POWER IN NUMBERS

THERE ARE ABOUT 1,000 MILLION BACTERIA IN JUST 1 GRAM OF SOIL – LESS THAN 1/4 TEASPOONFUL GIVEN FOOD AND WARMTH, THEIR NUMBER CAN DOUBLE IN 20 MINUTES.



Paul Raymond

fectured with amoebas is drunk, these protozoa enter the host and set up home in the gut. One such amoeba causes dysentery in humans. Once inside the host's gut, it starts to become active, irritating the tissue and upsetting the normal gut function. Dysentery results in stomach pains with diarrhoea, which can lead to dehydration.

In countries where medical care and pure drinking water are not easily available, dehydration is a most serious symptom. If more than 15 per cent of your body fluid is lost you will die. Drinking water infested with protozoa is a common cause of a usually mild form of

dysentery called 'holiday tummy'. Dysentery can be prevented by purifying drinking water with chemicals or by boiling.

Parasites are another common cause of disease in the developing world. They live on or in other living organisms and feed on them. Most parasites live a very complicated life cycle. Schistosomiasis, for example, found mostly in central Africa, spends part of its life in freshwater snails. It lays eggs, which hatch into a free-swimming form. These leave the snail and may infest humans.

Fever bug

Swimming parasites can enter the body via the soles of the feet. Once inside the body, they continuously reproduce. After about six weeks, the victim develops a fever accompanied by a cough, pain in the joints and swelling of the liver. Newly formed eggs are excreted and voided by the victim (in urine and faeces) and these eggs enter the water and reinfect the snails.

Germ patrol

White blood cells are designed to destroy any germs that enter our bodies. Certain white blood cells – the T and B lymphocytes – work together to produce antibodies. These antibodies attach themselves to the specific germ they have been made to attack. That is why a BCG immunization for tuberculosis

makes you immune to tuberculosis bacteria. Your body has produced antibodies to the very small dose of TB bacteria in the immunization and will now remember how to make it.

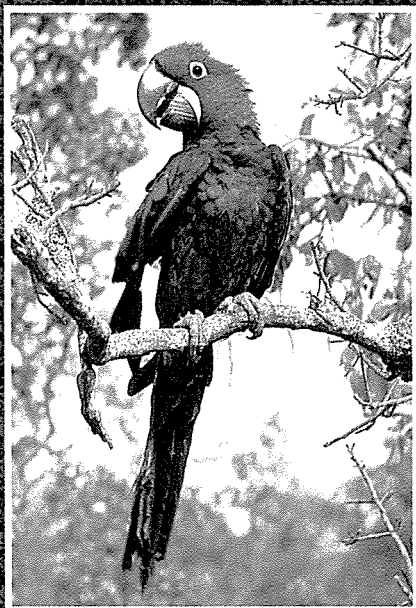
Prepared

If you come into contact with that type of bacteria again, your immune system will be armed and ready for it with the correct antibodies. Once the antibodies have been made, they are recognized by the lymphocytes, which pick them up and engulf them. But because the antibodies are attached to the germs, the lymphocytes also engulf and kill the germs in the process.

Steve Niedorf/The Image Bank



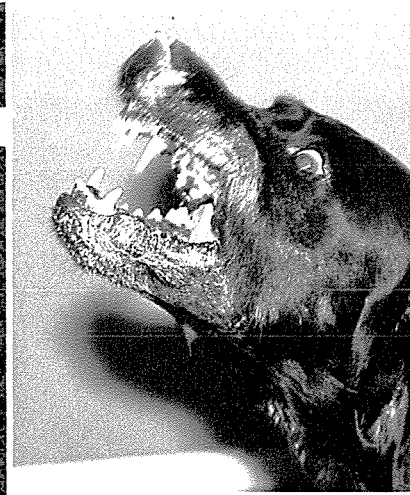
VIEW CARRIERS OF DISEASE



Parrots and parakeets are the main sources of psittacosis (an infectious disease), but about 70 species of birds are carriers of it.

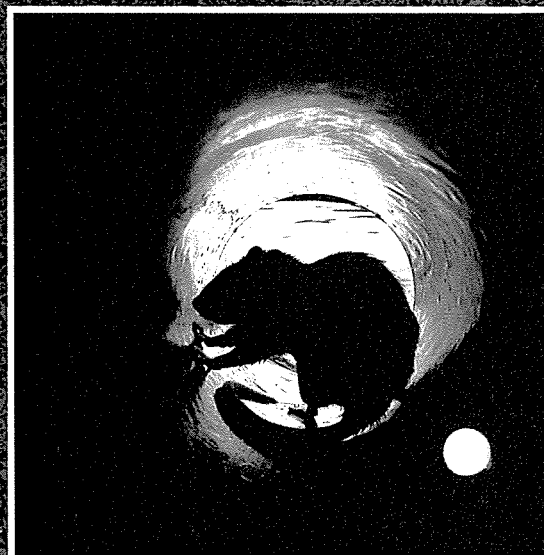


Bluebottles lay their eggs on uncovered raw meat, so the larvae have food when they hatch. The flies come into contact with many sorts of germ, which they spread.

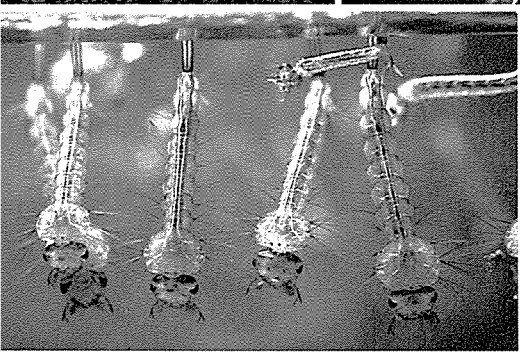


The rabies virus attacks the nervous system of wild animals and dogs, which can pass it on to humans.

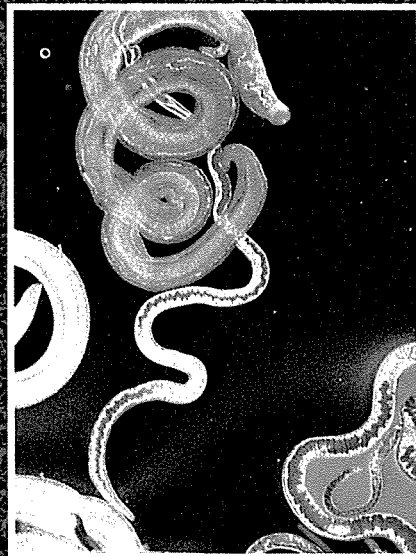
Mosquitoes are carriers of the bacteria that cause malaria. They lay eggs in pond water, where the larvae (below) develop.



Rodents and their fleas carry the bacteria that cause plague in humans. Sewer rats are especially infested.



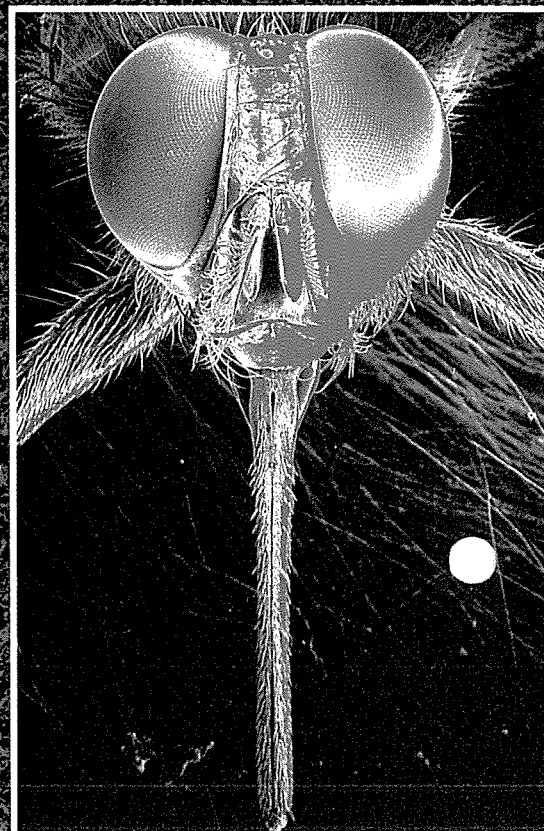
A pair of blood flukes (the male is thicker); these can live in the intestines of human beings and cause dysentery.



A horsefly bites through skin with scissor-like jaws. All sorts of germs survive in the blood it draws and are passed on to its next victim.



The African tsetse fly – a large blood-sucking fly – carries the germs that cause sleeping sickness.



Harold Schultz/Bruce Coleman Ltd

Dr Jeremy Burgess SPL

Stephen Dalton/NHPA

John Walsh SPL

Martin Dahn SPL

Stclair Stemmers SPL

Dr Jeremy Burgess SPL

ZEFA



THE FIGHT TO SURVIVE



-  TERRITORIES
-  PREDATORS
-  SHELTER

THE INSTINCT FOR SURVIVAL is shared by all animals, including ourselves. To survive, we all need food, shelter, the ability to avoid other creatures who might harm us and the means to reproduce our own species. These basic needs shape us and the world in which we live.

Of all an animal's basic needs, food is the most important. To ensure a supply of food, most creatures stake out an area of land — their territory — which they defend against other animals, usually of the same species.

Staking a claim

An easily spotted example of territorial behaviour is that of the robin. A robin will mark out a feeding area about the size of two back gardens and defend it vigorously against any intrusions by other robins. Individual robins patrol their territories regularly, announcing their ownership by singing. On meeting an intruder, the robin will attempt to frighten it away by a display of aggression, only resorting to fighting if all else fails.

Another easily observed example

of territorial behaviour is that of the domestic cat. The cat uses scent, spraying strategic points with a mixture of urine and musk produced from a special gland at the base of its tail. Cats performing this kind of marking dance up and down on their back legs, their tails straight up, as they eject the scent marker. Both male and female cats indulge in this activity, although the scent from the tom, the male cat, has the stronger smell. Scent marking (through the use of the special scent glands, urine or dung) together with sound and visual dis-

plays are the main ways in which animals mark out their territories.

While most animals defend their territories against others of their own kind, they are quite willing to share space with other species who do not eat the same sorts of food and do not present a physical threat. A robin will chase off other robins but will ignore birds such as sparrows, finches and tits, that it does not consider a threat.

Not all animal territories are fixed. On the great grasslands of central Africa, animals such as wildebeest and zebra migrate thousands of



Wolves kill to get food and in self-defence. Deer are typical prey. An adult deer may be several times the size of one wolf, so the wolves hunt in a pack, bringing down a deer that is too young, old or feeble to defend itself or get away. The number of wolves in a pack is about 20 — including a dominant male and female pair, cubs and related adults.

Udo Hirsch/Bruce Coleman Ltd





A giraffe guards her calf against a group of lionesses. It is the lionesses who usually do the hunting, taking the meat back to the rest of the pride.

and wolves will bury part of their latest victim as an emergency store of meat, in case it is a while before the next kill. Hedgehogs gorge themselves during the summer and autumn to build up reserves of fat, on which they live during their winter hibernation.

Deep sleep

Hibernation is a very effective method of surviving the cold of a long winter and the lack of readily available food. When hibernating, an animal's body behaves as though it were in a very deep sleep, with heart and breathing rates at the minimum necessary to maintain life. In this state, the animal's bodily functions can be fuelled from the fat

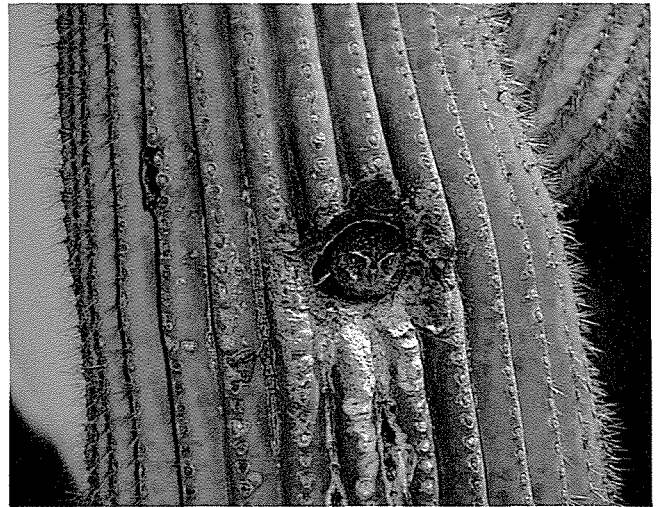
Jonathan Scott/Planet Earth Pictures

kilometers each year to areas where the grasses they eat are growing at particular times. They travel in great herds; if a predator approaches, say, a herd of zebra, the herd will close up and in the confusion it is less likely that one zebra will be singled out and killed. Mammals, birds and fish all use this technique of massing together to confuse predators.

Hunting in packs

Many hunting animals — lions and wolves, for instance — work in packs to deal with quarry that behave like this. In North America, wolves prey on elk and bison. During the chase, relays of wolves take over from one another in order to

An elf owl has taken over a nest hole in a cactus plant. The hole was probably dug out of the cactus by a woodpecker. When the hole was originally pecked, its inside dried out and became impermeable, so that the cactus should not lose any essential water through the hole.



Jen & Des Bartlett/Bruce Coleman Ltd

Kenneth Lucas/Planet Earth Pictures



A sea anemone acts as protector and provider for a pair of clown fish which are immune to its stinging tentacles.

A school of snappers confounds a predator by keeping together so that it is difficult to single one fish out for the kill.

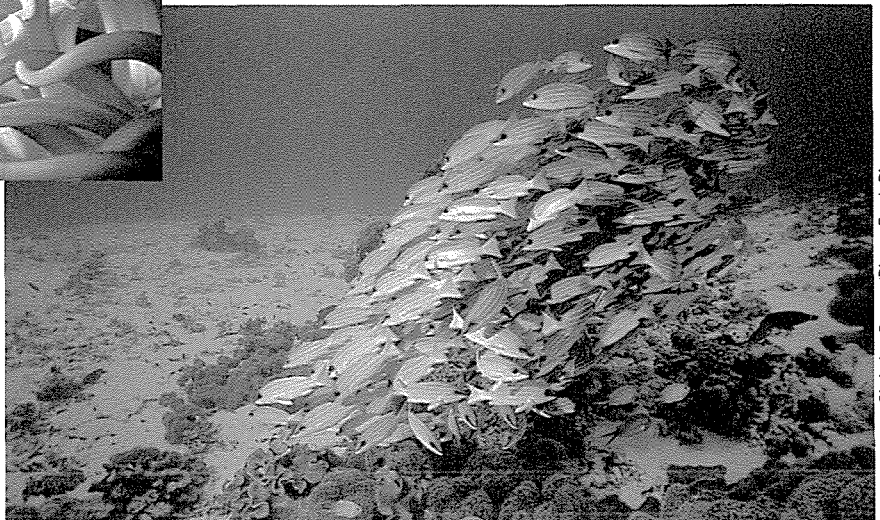
store built up during the summer, the fat also being very good insulation against the cold.

Hamsters build up a store of food for the winter — as much as 15 kg in weight — then go into a cycle of partial hibernation, when the temperature drops to 4°C and below. Every five days or so, they wake up for a meal.

Shelter is almost as important as food in the survival game. Animals need some place to escape from

exhaust the victim and not themselves.

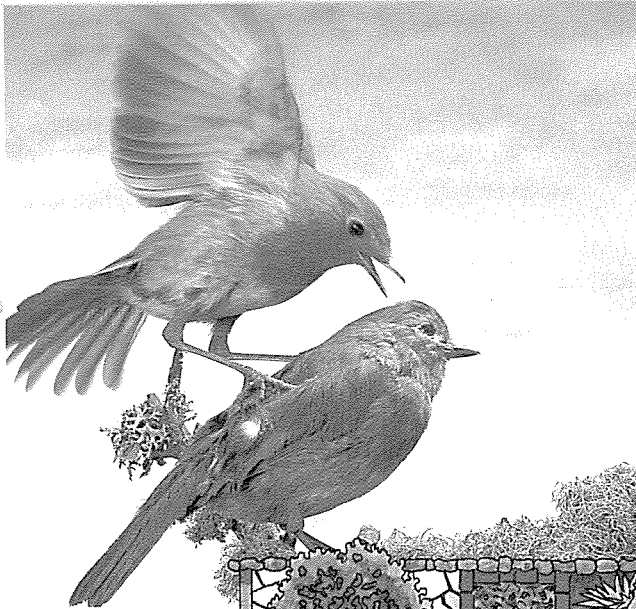
Some creatures store food against hard times. In northern Europe and North America, squirrels stockpile nuts and grains to see them through the winter months to the following spring. Foxes, hyenas



Christian Petron/Planet Earth Pictures



A robin's territory may extend over one or two gardens. The robin regularly visits certain observation points. It will chase away or even attack another robin, but allow other birds to feed. A robin will hover around a gardener, ready to eat grubs and other titbits found in freshly dug earth.



Peter Hinchliffe/Bruce Coleman Ltd

either digging the burrow itself or using an abandoned rabbit warren. Sand martins drill 1½ metre nest burrows into the banks of rivers, lakes and ponds. More conventional bird nests come in all shapes and sizes. The house martin, a close relative of the sand martin, builds with clay, sticking the nest to the walls of buildings, under the eaves.

The African weaver bird, as its name suggests, weaves a nest from long grasses. Looking for all the world like a plant holder, weaver nests are suspended from tree branches — they display a dazzling

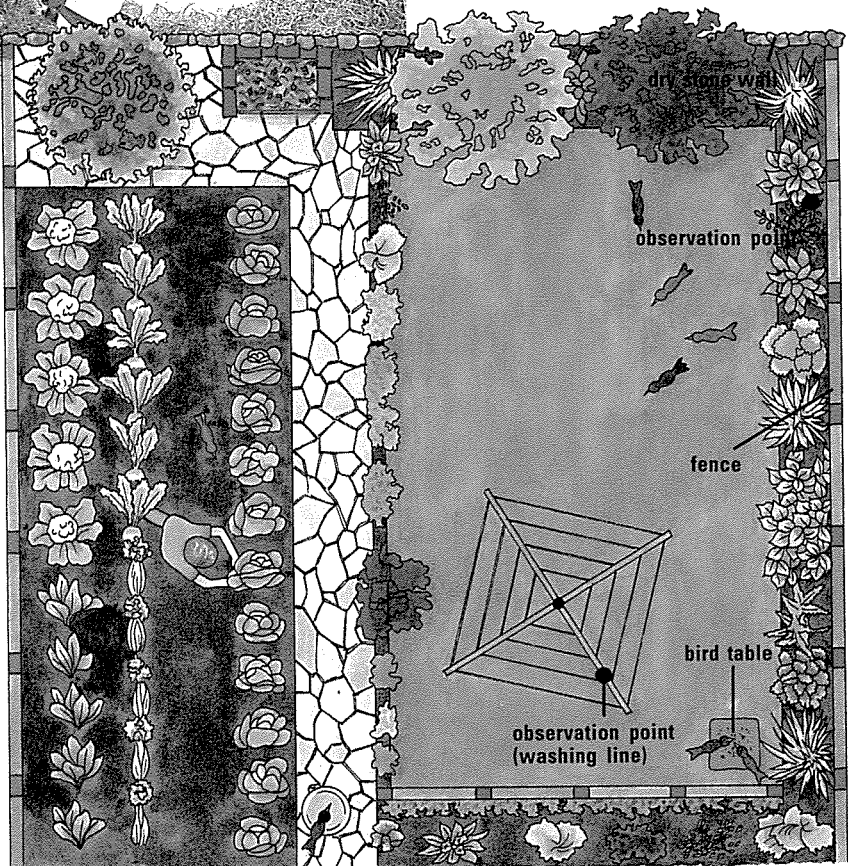
predators and weather as well as somewhere to rear their young.

Animal homes come in an amazing variety — from the bare earth which serves as a nest for the Arctic skua, to the 'mobile homes' of snails, to the 3-4 metre high 'skyscrapers' built from mud and excrement by termites.

Living underground

Burrows dug into the ground are a very common form of home for mammals. A typical warren has many tunnels and entrances. Badgers live in underground 'sets'. Badger sets can be lived in for many years, by generation after generation of the same family or 'clan'. One set in Gloucestershire, England, is thought to be over two hundred years old.

Some birds use burrows to nest in. The puffin builds a nest chamber at the end of a 3 metre-long tunnel,



Caroline Brodie

THE GUARD DOG



Trevor Wood

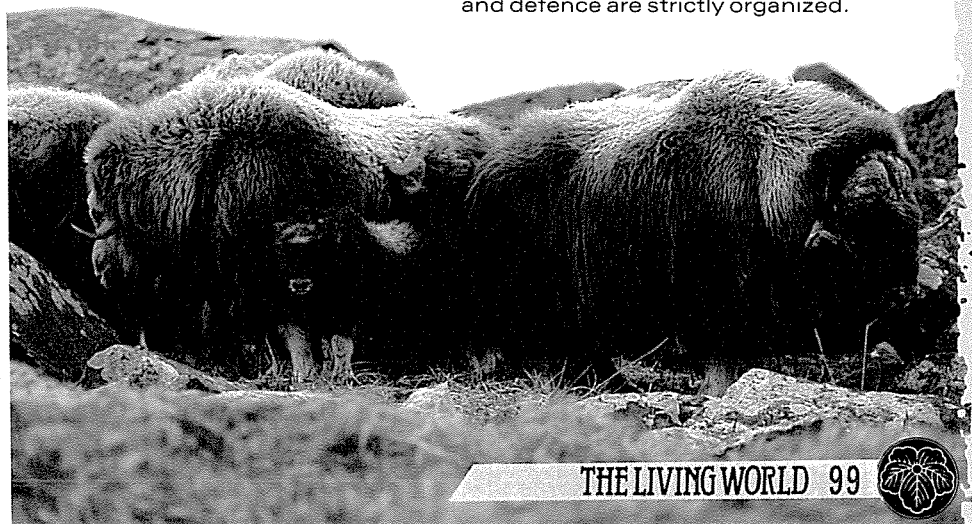
Today's domestic dog is a descendant of the wolf and shares some of the wild animal's instincts. Wolf packs have a central den — a safe place the pack protects from outsiders. Trespassers are attacked and driven away. All dogs have this same instinct. They establish a territory — usually the home of their owner — and will defend this area against intruders. Special breeding has accentuated this instinct in guard dogs such as Dobermanns (pictured above).

Francisco Erize/Bruce Coleman Ltd

Musk oxen threatened by predators form a circle with the adults with their massive horns facing outwards and the weaker young in the centre.

level of skill in their construction.

However, the true architects of the living world are ants, termites, bees and wasps. All of these are 'social' insects — they work collectively to serve 'queens' who have given rise to the whole of the colony. Within their world, duties such as food collection, feeding of the young and defence are strictly organized.



A brown skua snatches a penguin chick on the Falkland Islands in the South Atlantic. Penguins have few enemies except the skua, the leopard seal and Man. Skuas will eat anything from worms to small birds and mammals.



Francisco Erize/Bruce Coleman Ltd

wing designs to frighten off predators. Some even squeak.

The use of colouring as camouflage is very common and can be seen in insects, fish, birds and mammals. Few animals can match the chameleon, which can change its colour to match its background.

Camouflage is not just used for defensive purposes — predators use camouflage, too. If you look carefully at a lion, you will see that the stomach fur is a lighter colour than that on its back.

This is to minimize the contrast between those parts of the body which are in shadow and those which are in light. This makes the lion's body appear 'flatter' than it really is

To accommodate such rigid societies, these insects build marvellously complex homes with large numbers of different 'chambers' allocated to specific purposes, such as cell-like structures designed to house the developing eggs. Bees also build similar structures for storing food — these are the honeycombs containing nectar, honey or pollen.

Outside the home, animals frequently use camouflage or some

Adrian Davies/Bruce Coleman Ltd

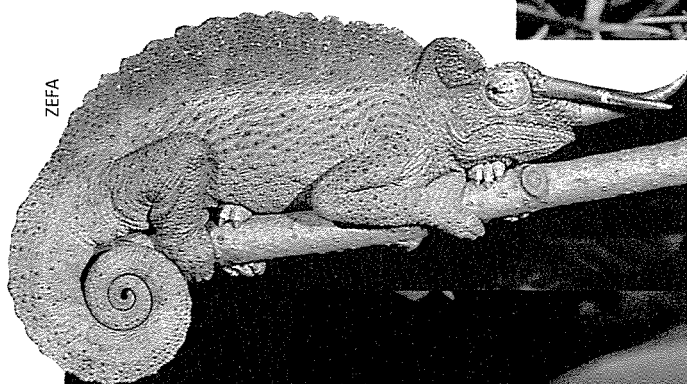


The emperor moth frightens off its enemies with spots on its wings that resemble large staring eyes.

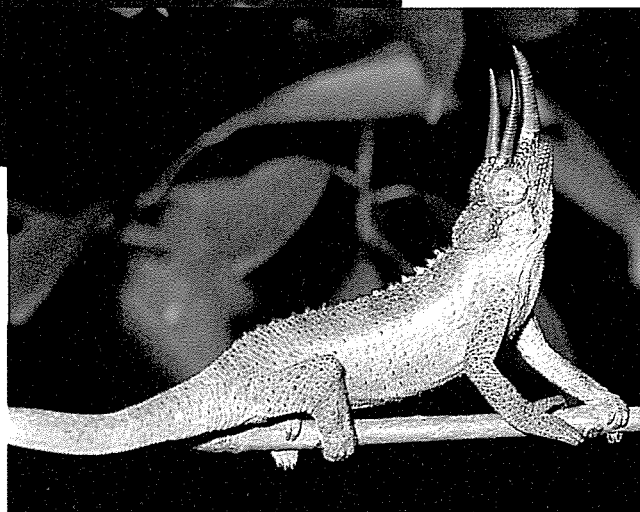
and, therefore, more difficult to see.

Less common than colour camouflage is the ability to look like the plant on which the animal lives. A very good example of this sort of camouflage is the stick insect which, when still, is almost impossible to tell from a twig. Different sub-species of this insect have evolved so that they look like the particular plants on which they live. But once spotted, a stick insect will try to frighten the attacker away. One sub-species imitates a scorpion, grabbing with its front legs and curling its abdomen upwards, like a scorpion's stinging tail.

ZEFA



A chameleon can change colour in minutes, depending on species, to blend in with its surroundings. This not only protects the chameleon, but also allows it to creep up on prey undetected.



Gunter Ziesler/Bruce Coleman Ltd

form of defensive system to survive or prevent attacks by predators. In terms of protection, a familiar example is the snail's shell. When threatened, the snail withdraws its fleshy body parts into the shell until the threat has gone away. The snail's shell also helps it to keep moist — vital for its survival.

Higher up the evolutionary chain, creatures such as porcupines and hedgehogs have evolved defensive spines which they can erect when

under attack. These spines have developed from hairs and are raised by an increase in blood pressure. Rolling into a ball protects the animal's underside and makes it virtually invulnerable to attack.

When a cat is angry, its fur bristles and it arches its back. All this is done to make it look as frightening as possible to an opponent. This is a common defence in nature. Many moth and butterfly species use flash colour and striking

Just amazing!

SOLID FOUNDATIONS?

A VILLAGE IN AFRICA IS BUILT ON TOP OF A MOUND 100 METRES ACROSS — CONSTRUCTED BY A COLONY OF TERMITES.



Paul Raymond



THE UNDERWORLD



- ☐ EARTHWORMS
- ☐ MOLE HOLES
- ☐ SAFETY UNDERGROUND

Adrian Warren/Ardea London

THE EARTH BENEATH OUR feet is teeming with life. Some 20 million species live in the surface soil. These vary from microscopic animals, plants and bacteria, to larger burrowing animals such as insects and mammals.

Bacteria are by far the most common organisms living in the soil. There can be as many as one thousand million of them in a gram of earth. Different types of bacteria perform different tasks. For example, nitrifying bacteria help to break down the nitrogen-containing chemicals in dead organic matter into nitrates, which can be absorbed by plants. Nitrogen-fixing bacteria live in the roots of peas,

Vampire bats live in huge swarms in caves in the southern parts of South America. At night, they fly out in search of large, warm-blooded animals. When they find one (inset), they pierce its skin and lap, rather than suck its blood.



clovers and other leguminous plants. They convert nitrogen in the air into a form that nitrifying bacteria can then turn into nitrates.

Fungi in the soil live on both living and dead animals. They, too, break down organic material to provide nutrients for plants.

There are also a large number of animals that live in the earth, such as worms, mites, spiders, beetles and slugs.



Eating soil

Earthworms are one of the animal species inhabiting the soil that are most often seen. More than two

The mole uses its extra-wide forelegs and powerful claws to shovel earth round behind it. Its snout is extremely sensitive to smell and vibrations of worms and insects in the soil.



ZEFA

hundred species of worm live in Europe. All of them live by burrowing in the soil and eating soil. They digest the organic material in it and excrete the rest as soft wormcasts,

of soil. Their constant burrowing allows air into the soil which is vital for plants to grow. Minute bristles on their bodies help them burrow through the soil.

You can chop an earthworm in half without killing it. The missing ends will simply regenerate and you will end up with two worms rather than one. Earthworms are also hermaphrodite. That is, they are both

Powerful claws are needed if you are going to burrow through the earth. The badger and the gopher (right) have hooked claws and curved palms to help them shovel earth.

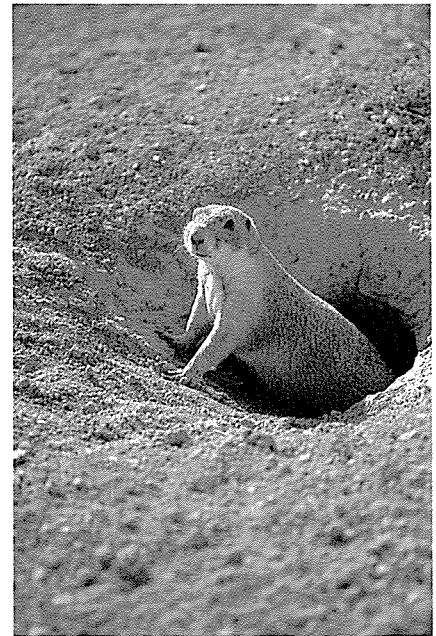
R. Mendez/Animals Animals/OSF



The North American gopher leads a solitary life. This extensive burrow houses just one female and her young – and contains everything they need to survive.

within the soil or on the surface, depending on the species. Several species of worm plug the tops of their burrows with leaves.

As many as 500 worms may make their home in a square metre



John Mason/Ardea London

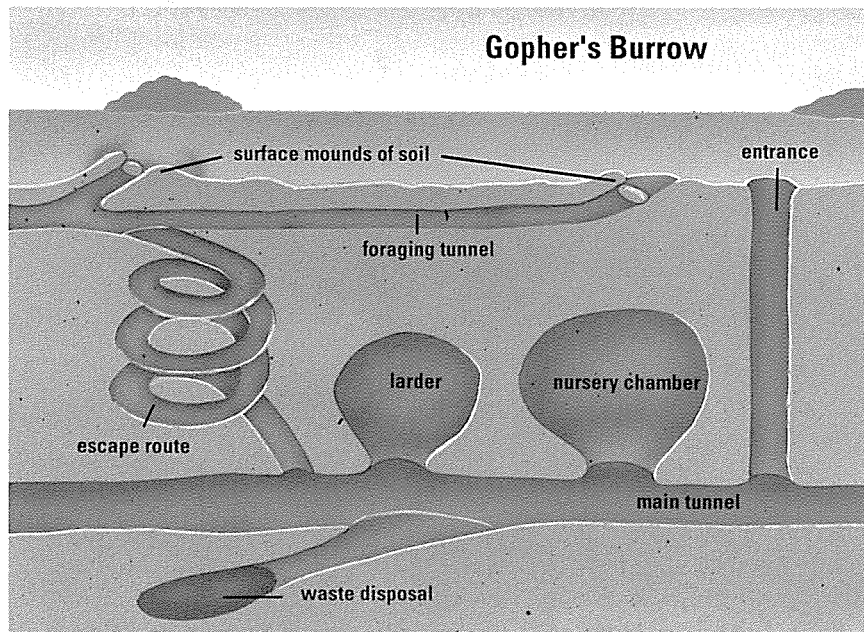
A blacktail prairie dog guards the entrance to its underground colony which may house hundreds.

sexes at once – male one end, female the other.

Worms rise to the surface when it rains or when the dew settles in the morning, otherwise they would drown. There, they are very vulnerable to birds and hedgehogs, which eat them. Some birds drum their feet on the ground, to make worms think it is raining. Below ground, moles are their only enemies.

The mole is a fast, tireless digger and the shape of its body is well

Gopher's Burrow



Mark Franklin



suited for burrowing. It has a large pointed nose, a wedge-shaped head, and large forelegs. Its front paws, which turn outward, have long broad nails. The forelegs work like shovels, scooping out the earth. Whiskers on the face help these short-sighted animals feel their way underground.

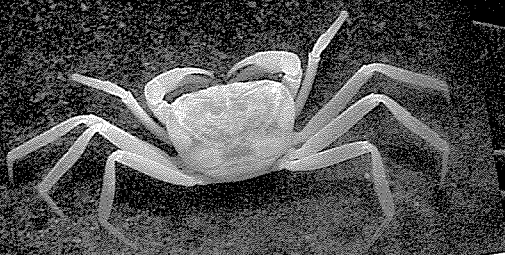
Another animal that spends as much time underground as a mole



Chris Howes/Planet Earth Pictures

Prolonged darkness

has its effects. The clear water cave crab from Sarawak (far left) is completely white. The characin (left), a cave-dwelling fish from Mexico, is blind. And this cave insect from South Wales (above) has no need of dark pigment to protect it from the Sun's rays.

Philip Chapman/Planet Earth Pictures
Jane Burton/Bruce Coleman Ltd (middle)

is the North American gopher. These small animals live in long tunnel complexes from which they seldom emerge. They dig their tunnels with the large claws of their front feet and also their front teeth.

Gophers spend much of their time patrolling their tunnels which can be as much as 240 metres in length. They do not like other gophers entering their homes except during the breeding season. A nearly hairless highly sensitive tail allows the gopher to feel its way backwards through its tunnels.

Muskrat burrows

The North American muskrat lives in burrows in the banks of streams. Muskrat houses usually have more than one underwater entrance as well as an entrance situated

above ground level.

The chipmunk, a small striped animal that lives in burrows in Asia and North America, also makes distinctive homes. It digs two tunnels which meet underground in a large nesting area. The soil is pushed out to plug the entrance to one of the tunnels, which is only used in an emergency.

Sets are the burrow homes of

most of its time underground, only venturing above ground to forage for insects.

Large numbers of prairie dogs live in underground colonies, or 'towns'. Prairie dogs are not actually dogs but members of the squirrel family. Their name comes from their distinctive, shrill, dog-like bark. Several thousand – or even a million – prairie dogs may live together in a

The naked mole-rat from East Africa is literally naked. It needs no fur to keep it warm – or to protect its skin from the Sun's rays. Its protruding front teeth are used to help it burrow through the hard earth from which it rarely emerges.



Just amazing!

NOW YOU SEE IT...

THE AARDVARK IS SUCH A SUPER-FAST DIGGER THAT WHEN AN ENEMY APPROACHES, IT DIGS ITSELF A HOLE TO HIDE IN INSTEAD OF RUNNING AWAY.



Paul Raymond

badgers, whose strong front claws and powerful bodies make them efficient tunnellers. These sets are usually no more than two metres underground and, once dug, they may be used for centuries by generations of badgers.

The pink fairy armadillo is also a formidable burrower. It makes its burrow by digging with its front legs and pushing with its snout. A native of South America, it spends

colony. This is divided into wards, which in turn are divided into family groups, or coteries. Each coterie has an entrance tunnel that goes down around four metres to a series of burrowed rooms for sorting food or sleeping in. The advantage of this communal living is that lookouts at the tunnel entrances can warn of danger. A high-pitched bark alerts the others to dive underground.

Jane Burton/Bruce Coleman Ltd



Most rabbits live in burrows that they did not actually dig. Whenever possible, they tend to move into those abandoned by badgers, prairie dogs, skunks or woodchucks. Rabbits do burrow though, extremely well, and use their skills to extend homes they have found. A large rabbit warren may house as many as 400 rabbits with some 2,000 entrances. Tunnels within the warren can act as roads, places to sleep or places to rear young.

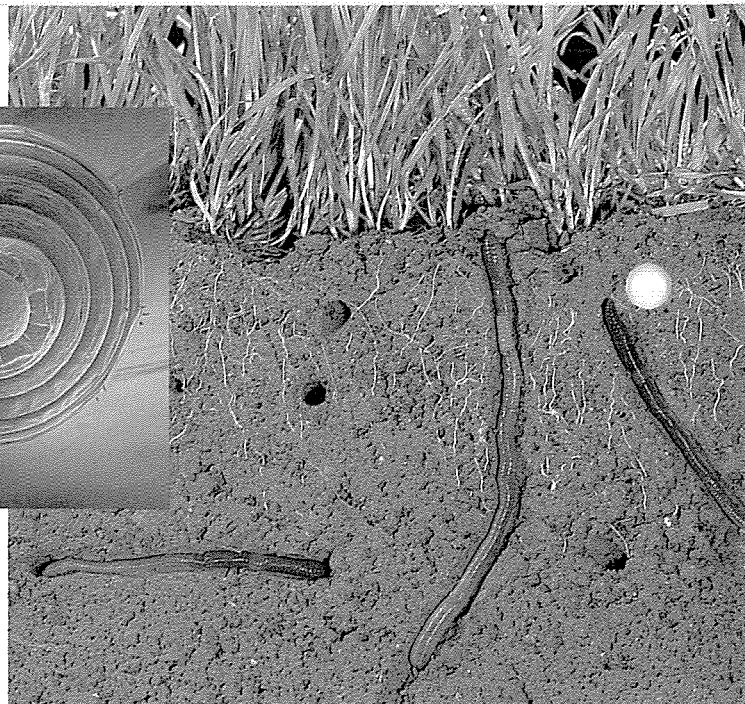
Trapdoor threat

Tarantulas are the world's largest spiders and many types of them dig burrows as nests. One variety, the

David Scharf/SPL



Earthworms head for the surface when it rains, so that they do not drown. The worm's mouth (inset above) swallows the soil.



only their unblinking eyes visible.

Camel crickets in the south west of America have basket-shaped clusters of spurs on their hind legs to help them dig into sand dunes. Sand in American and African deserts is also the home of desert-living grasshoppers that exhibit a

type of behaviour known as 'self-burial'. Rather than make an elongated burrow, the grasshopper rests on the surface of the sand and moves back and forth until it has submerged itself. The aim of this strange behaviour is protection.

Sleeping frogs

Several species of frog live deep under the desert. On the rare occasion it rains, they emerge and lay spawn in pools of water. The spawn changes via metamorphosis into frogs in weeks. When the pools dry up, the frogs go underground again and lay dormant – sometimes for years – until it rains again.

Hedgehogs and dormice find underground burrows to hibernate in for the winter. Their body temperature drops and their metabolism slows down to conserve energy. What energy they do need is provided by their fat stores.

Jean-Paul Ferrero/Ardea London

The trapdoor spider puts a lid over its burrow. When prey passes, it flips the lid open to seize the unsuspecting insect.



Jan Taylor/Bruce Coleman Ltd

trapdoor spider, digs a tunnel and covers it with bits of moss and silk webbing.

When an unsuspecting insect walks too close, the spider flips the trapdoor open and captures its prey. The burrow, which can be 25 cm deep, is also used for protection and as a nest for young spiders.

Hamsters burrow underground homes where they hoard vast quantities of nuts, seeds and roots.

Buried in sand

Some cockroaches burrow in sand, soil and rotting wood with their strong and short legs. Crickets burrow small tunnels which can provide shelter and a place to lay eggs. They also feed on the roots and tubers they find while digging.

Desert vipers trap their prey by lying in wait under the sand with

Sean Morris/Oxford Scientific Films

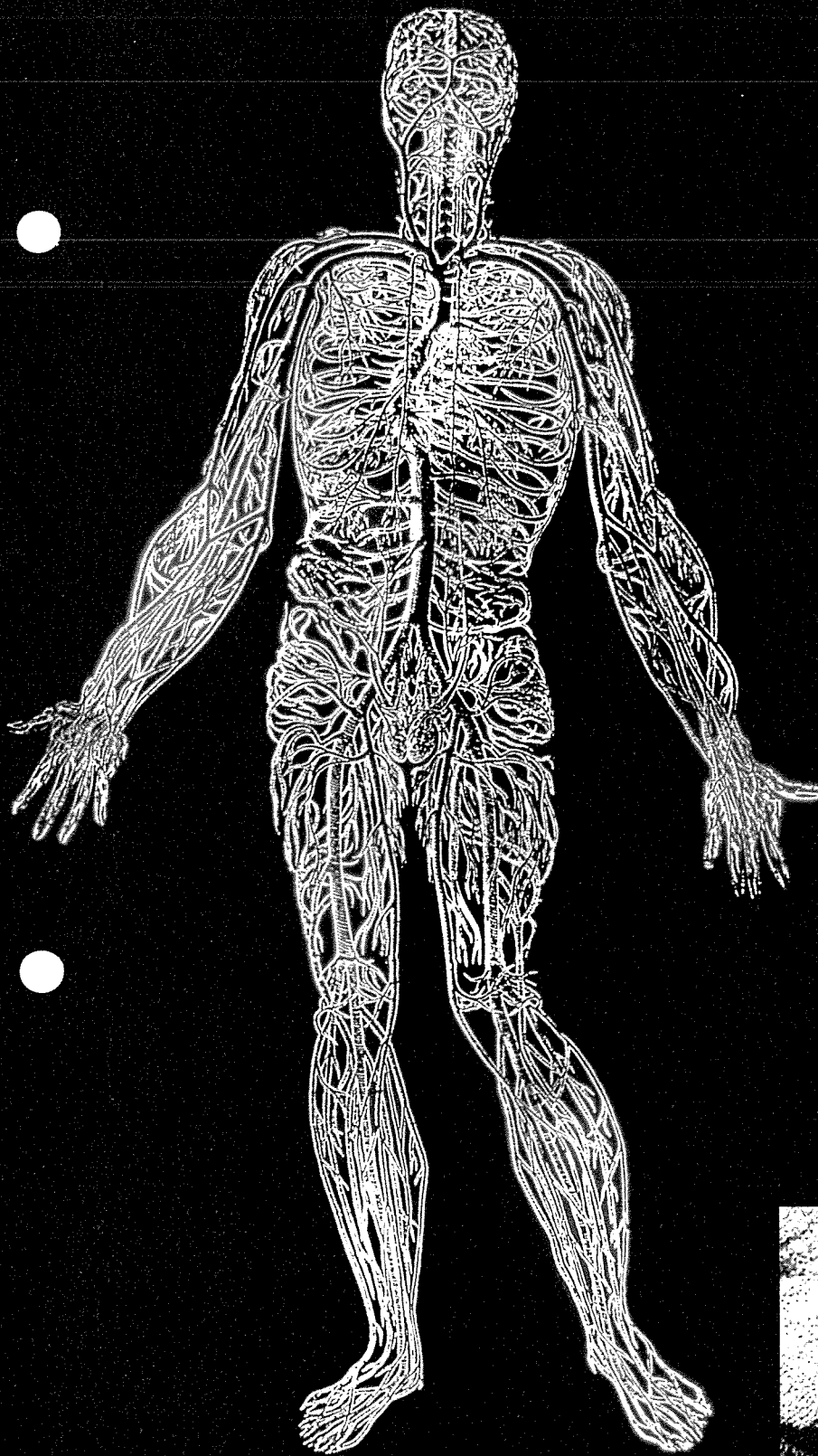


The spider then emerges to drag the insect back into the lair, where it is devoured at leisure.

A type of tarantula – the largest of all spiders – the trapdoor spider is found mainly in East Africa and throughout Western Australia.

Mantis Wildlife Films/Oxford Scientific Films





- MOVEMENT
- THE SENSES
- CONTROL CENTRE

THE HUMAN BODY IS A better machine than any engineer can design. Athletes can develop their bodies to sprint at about 50 km/h, bowl or throw a ball at more than 140 km/h, jump to heights of 2½ metres, yet retain the precision, should they wish, to thread a needle.

The body is made up of a number of maintenance and performance systems that have evolved through millions of years. The circulatory system, for instance, is a remarkably compact network of vessels which carry blood around the body. In this network there are about 37,000 km of capillaries, veins and arteries. Blood is pumped from the heart at the rate of 5½ litres a minute when the body is relaxed and up to 17 litres a minute during vigorous exercise. During a lifetime the heart may pump 2,000 million times without missing a beat — a feat of design well beyond the best of today's engineering.

Muscle power

Muscles account for about 30 per cent of the human body and provide power for the body to move — from the precision actions of the hand during writing, to the explosive flexings of the leg muscles during

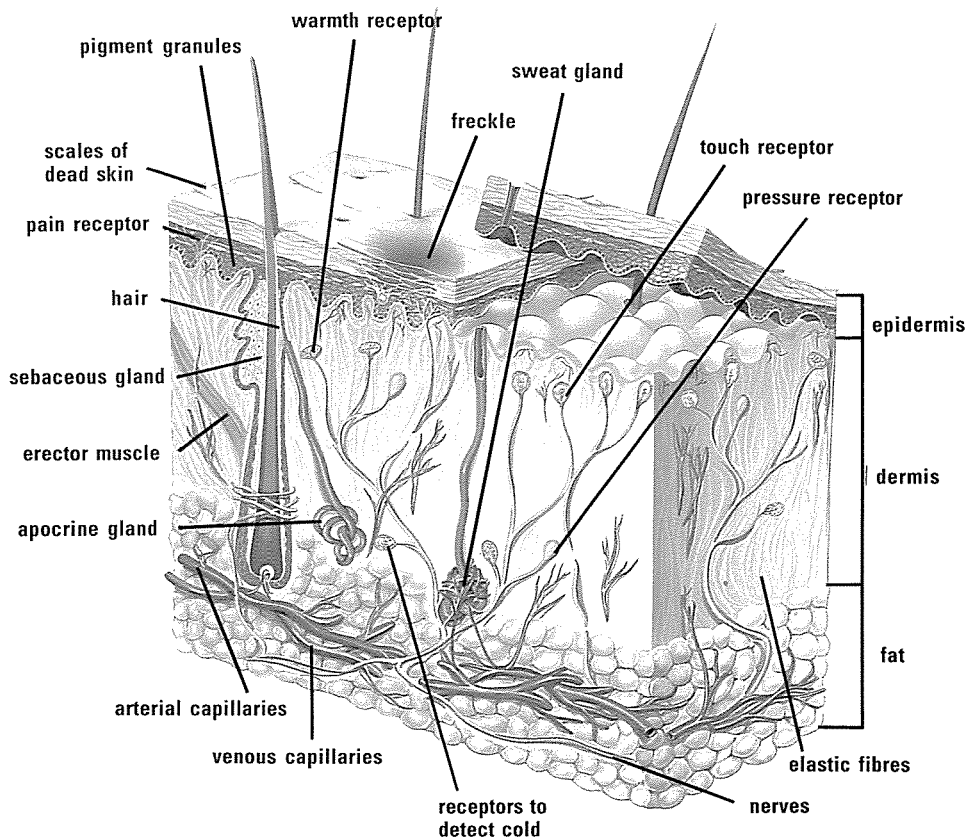
The circulatory system is a network of branching blood vessels that carry blood pumped by the heart to the tissues around the body.



HUMAN MACHINES



Structure of the Skin



running. There are more than 600 voluntary muscles which receive instructions from the brain to carry out functions such as running, jumping, walking, and blinking.

Involuntary muscles are vital to maintain body systems. For example, the heart is a muscle which pumps blood through the body; chest muscles and the diaphragm expand

the chest cavity to aid breathing; and muscles in the uterus help in the birth of a baby.

Muscles are biological machines, converting chemical energy from food into mechanical energy to produce movement. Even the most unfit person can generate several kilograms of force across each square centimetre of muscle, and the muscles at the back of the hip can generate well over 1000 kg.

Relaxers

The muscles are made up of thousands of parallel fibres which contract by a small amount when they receive a signal from the brain. The effect of the combined contractions is to shorten the muscle, which pulls on the tendons to move the limbs.

Two sets of muscles work on the same limb – one contracting while the other relaxes to bend it. To

The skin is the largest organ of the body. It helps to regulate body temperature, and it contains the receptors that give the sense of touch.

straighten the limb, they reverse roles – the one that was contracting now relaxes while the other goes into contraction.

The joints between bones enable the muscles to provide controlled movement. There are more than 200 joints with varying degrees of movement. The shoulder joint, which has a ball-and-socket design, affords the arm a lot of movement in all three planes, whereas the ankle can move in only one plane. The range of movement of each of the 100 or so vertebral joints in the spine is also small, but they act in combination and enable the back considerable movement.

Shock absorbers

Joints are more efficient and last longer than any machine equivalent. To reduce wear caused by friction,

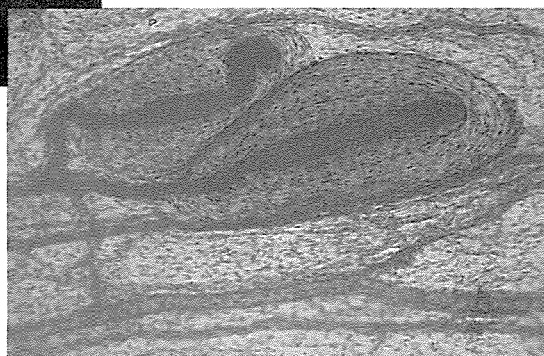


A single human taste bud, photographed through a microscope, showing the cells that identify sweet, bitter, acid and salt.

Biophoto Associates/Science Photo Library



The human hand has a complicated arrangement of bones, joints and ligaments that, together with the use of touch-sensitive cells (right) in the skin, enable it to grasp and lift large, heavy objects or to manipulate tiny objects, such as a needle and thread.



Eric Grave/Science Photo Library

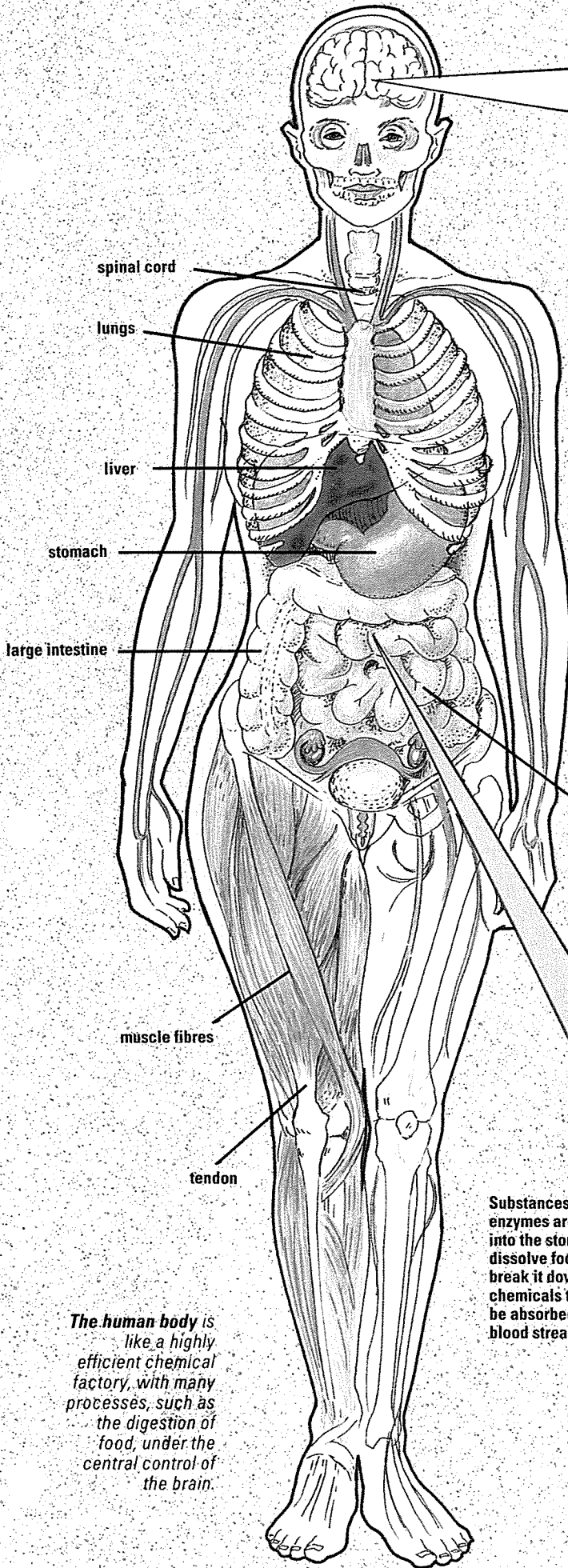
the knee, hip and ankle joints, for example, are held together by ligaments – tough fibres of collagen – and cushioned in a pocket of lubricating synovial fluid. This system of lubrication and suspension enables the body to withstand strenuous activity and stresses up to 20 times the force of gravity.

Sometimes, as the body ages, the joints do not work so smoothly and arthritis (inflammation of the joints) can set in, causing pain and difficulty of movement.

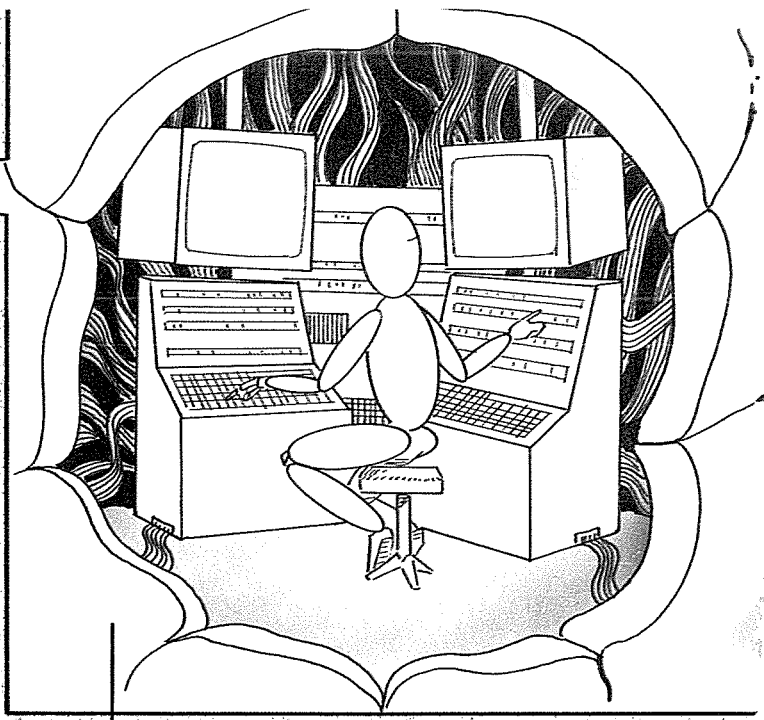
Mobility, however, depends not just on muscles and bones, but also on balance to co-ordinate movement. The inner ear is the organ of



Anatomy of the Female Body



The human body is like a highly efficient chemical factory, with many processes, such as the digestion of food, under the central control of the brain.



The brain works on two levels to control:

1. involuntary functions, such as breathing and heartbeat, and
2. voluntary actions, such as contracting muscles to move the limbs.

balance. It tells the brain, for example, which is up and which is down, the angle of the head and the direction of movement.

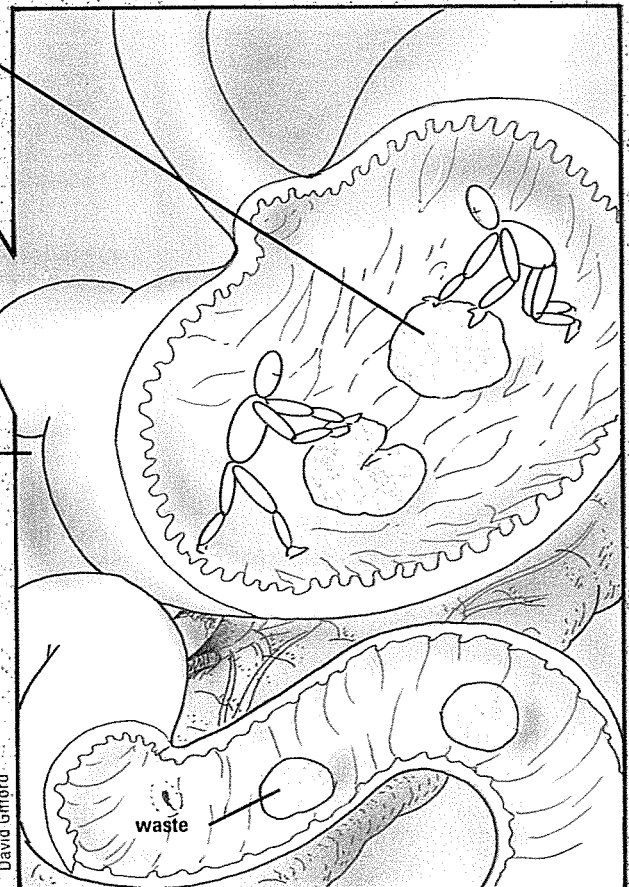
The angle of the head is detected by a number of small chambers within the inner ear which are lined with tiny hairs. On top of these hairs are crystals of calcium carbonate, which shift when the head moves. These shifts generate electrical impulses which the brain uses to work out the angle of the head.

There are also three bony, semi-circular, fluid-filled canals in the inner ear. When the head rotates or undergoes acceleration, the fluid

small intestine

food

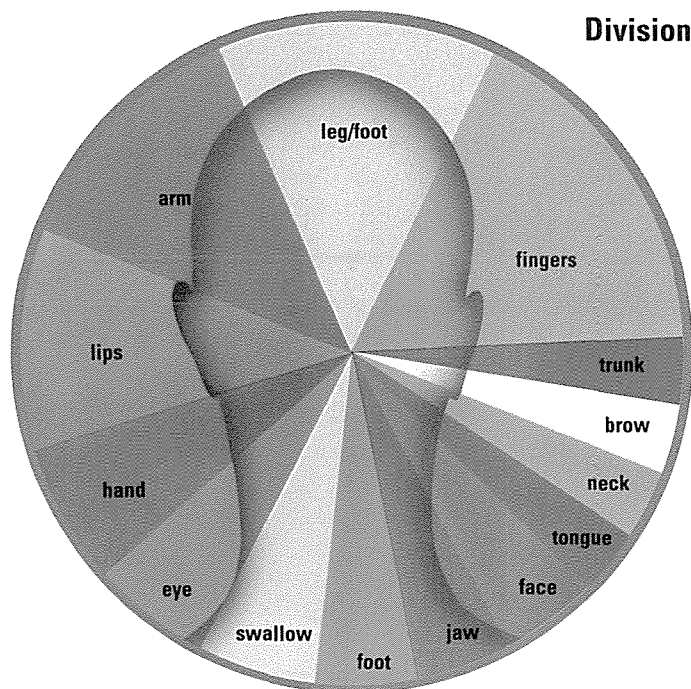
Substances called enzymes are released into the stomach to dissolve food and break it down into chemicals that can be absorbed into the blood stream.



waste

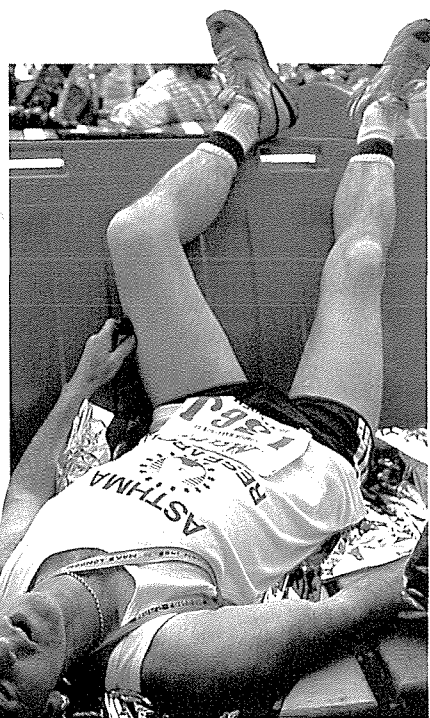


Division of Brain Power



An athlete collapses from exhaustion, having pushed his body to the limit while taking part in the London Marathon. Many inexperienced runners suffer injury from this sport.

Different parts of the body are controlled by certain areas of the brain. The lips, arms, legs and fingers are served by large areas.



Kathy Bebbington/Action-Plus

Mark Franklin

moves and triggers receptor cells in the canals to tell the brain the direction and speed of the head.

The ear can detect a wide range of sounds and distinguish between sounds that are only slightly different in intensity. The outer passage of the ear, or auditory canal, doubles the sound energy passing through it by targeting the sound on the ear drum. The sound then passes to the three smallest bones in the body which vibrate and amplify the sound another 30 times.

Once past the tiny bone network, the sound arrives at the cochlea – a fluid-filled, snail-shaped structure. The cochlea contains more than

20,000 hair cells, each of which may have 100 hairs protruding from it. These hair cells are moved back and forth by the sound waves passing through the fluid.

Different hair cells respond to different sound frequencies and each cell sends a message along the auditory nerve to the brain. The

cells which sample molecules to allow the brain to detect bitter, sweet, salt and acid.

The sense of smell depends on yet another set of receptors. These are in the mucus-covered nerve endings which project from the lining of the nasal cavity. They can detect a single molecule.

The human brain is like a giant computer yet weighs less than 1½ kg. It contains roughly ten thousand million nerve cells, each of which can make 250,000 interconnections with other cells. The brain is the controlling centre for our thoughts, movements and body functions. It is isolated from the rest of the body by a protective barrier of fluid.

This protective barrier is provided by a wall of cells lining blood vessels around the brain. These cells regulate the passage of chemicals between blood and cerebrospinal fluid, which bathes the brain and keeps out bacteria.

COMA

A coma is like a very deep sleep. It can be caused by severe illness, a drug overdose, too much alcohol or a head injury. A person in this state does not respond to any form of stimulus and cannot be awakened, often for long periods. The longest recorded coma is 37 years 11 days, which befell a 6 year old American girl, undergoing an appendix operation. She died, without recovering consciousness, in 1978.

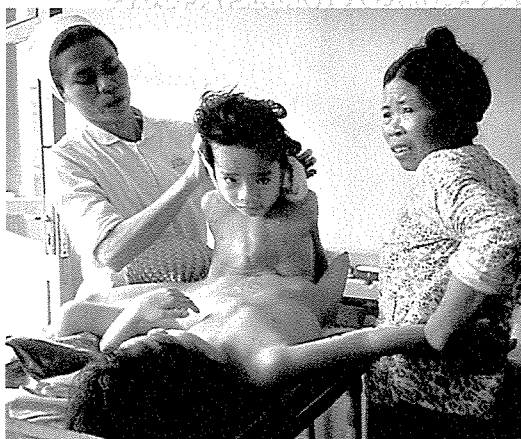
messages are decoded by the brain, which can detect the direction of a sound source by comparing the arrival times of a sound at each ear. The brain can judge the direction of the sound even though the difference in time of arrival at the ear may be only one hundred-thousandth of a second.

Wrapped up

The largest organ in the body is the skin. It performs the important function of protecting and holding the body, and is an important point of contact with the environment. It is the organ of touch, containing sensitive cells which tell the brain the difference between hot and cold, wet and dry, soft and sharp, and can detect stimuli only 3 mm apart in the most sensitive areas, such as the finger tips.

The tongue, also, is covered by a sensitive layer containing receptor

SIAMESE TWINS



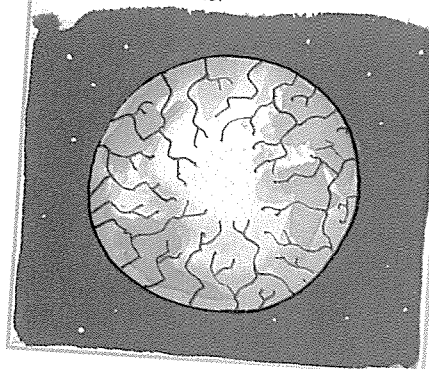
Gamma/Frank Spooner Pictures

Non-identical twins occur when two eggs are fertilized. Identical twins result when a single fertilized egg divides. An incomplete division produces Siamese twins. Some Siamese twins can be separated, but not Masha and Dasha, who live near Moscow. The sisters are two people and they each have a pair of arms, but their spines are merged into one, and they share just one pair of legs and one bowel.

Just amazing!

BLOODLINES

IF ALL THE BLOOD VESSELS IN THE HUMAN BODY WERE LAID END TO END, THEY WOULD STRETCH AROUND THE EARTH FIVE TIMES.



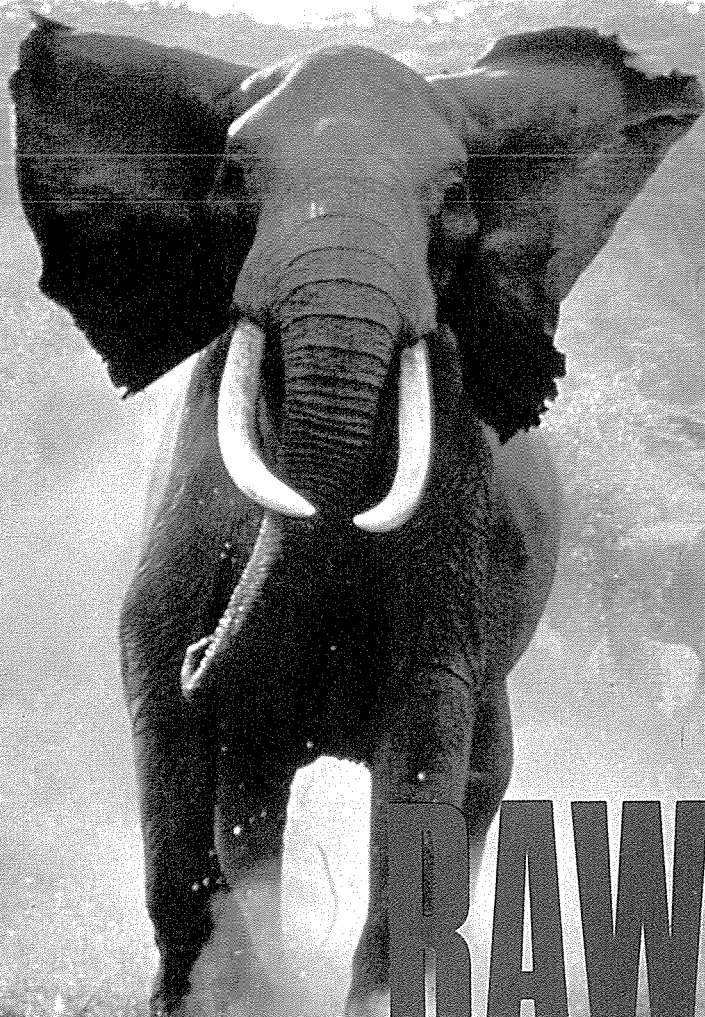
Paul Raymond



 THE TOUGHEST

 THE FASTEST

THE DEADLIEST



RAW POWER

Survival Anglia

THE STRONGEST ANIMAL IN the world is not the elephant. The dung beetle, found in the tropics, can support 850 times its own weight on its back – while an elephant can carry only a quarter of its body weight.

The elephant is not the biggest animal, either – the blue whale is the largest animal ever known to exist. It grows up to 30 metres in length and weighs up to 140 tonnes – about the weight of 30 full-grown elephants.

Tough guys

And you would think that an elephant is pretty tough, but not as tough as the larvae of the chironomid fly which can live at temperatures as low as -270°C and as high as 102°C . It is also the toughest animal – it can survive being totally dehydrated.

However, the elephant does have the distinction of being the largest living land animal. It can grow up to 4 metres tall at the shoulder, and the largest ever weighed over 12 tonnes. Tusks can grow up to 3.5 metres in length and weigh over 100 kg.

The largest crocodile, the Nile Crocodile of northern Africa, is around 7 metres long, but will attack an animal bigger than itself. Crocodiles lie in the water with just their eyes above the surface. When they get to within 6 metres of their prey, they attack. A few flicks of their powerful tails carry them that distance at amazing speed.

Despite powerful teeth – which are used solely to seize prey – the crocodile cannot chew its food. It either has to swallow it whole, or tear it to pieces by gripping one part of the carcass with its teeth, then rotating on its axis.

The Komodo dragon of Indonesia is the largest species of lizard. It grows up to 3 metres long and lives mainly on small pigs. They can run up to 16 km/h to catch them.

The peregrine falcon can fly at over 360 km/h. The golden eagle dives at more than 240 km/h and a whole range of birds, such as species of swift and goose, fly at more than 100 km/h, while man's top speed is a measly 50 km/h.

The fastest animal on Earth is the

The elephant may not be the strongest, or the biggest, or the toughest animal in the world. But when angry it can charge at speeds of up to 40 km/h over distances of 45 metres.

cheetah, a species of big cat with long and slender legs which has a top speed of around 100 km/h. The cheetah can reach a speed of 72 km/h in two seconds from a standing start. It has this incredible acceleration because, in contrast to many cats, the cheetah has a flexible backbone which allows its hind legs to overtake its forelegs in every bound.

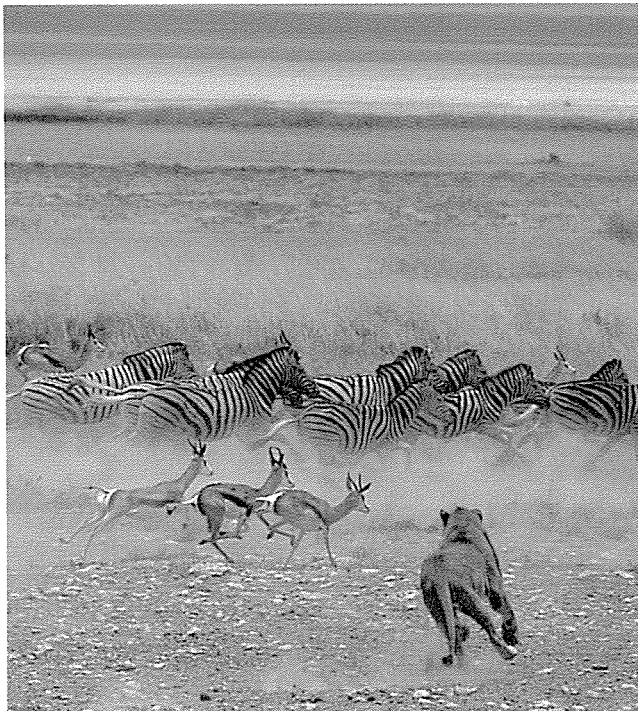
Not too far behind in the speed stakes are certain types of gazelle and antelope. Racing greyhounds reach speeds of 70 km/h.

Sea speed

In the sea, once the killer whale gets some momentum behind its giant bulk, it can swim at over 50 km/h. The common dolphin and the salmon are around 10 km/h and 20 km/h slower.

The sperm whale can dive to over





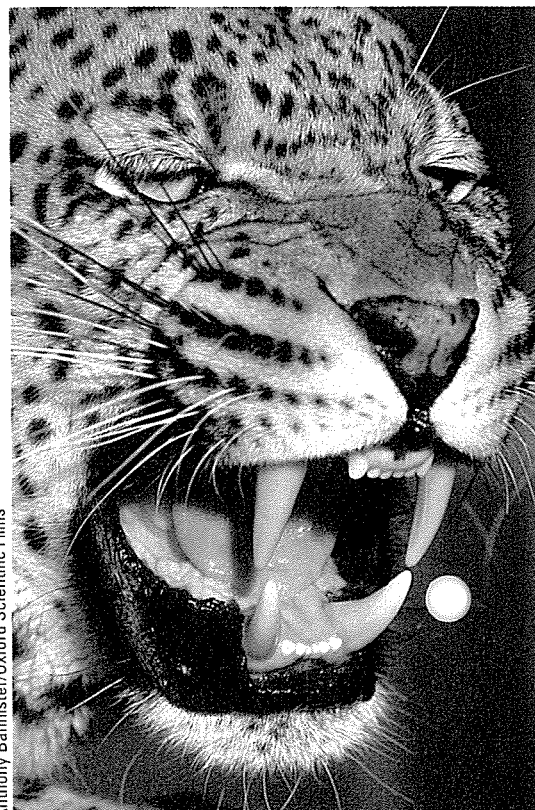
Young male lions can cause havoc among herds of springbok and zebra – once they have learned the right tactics. Speed and strength are not enough. Brain power is needed to catch prey that can run faster.

cells which, upon triggering, inject paralysing poisons into fish or smaller prey. Some marine snails have a poisonous tooth which they use to stab their victims, while insects like bees and wasps have their sting in the tip of the abdomen.

Poisonous fish may have defensive spines on their bodies. Sting-rays have venom glands on their dagger-like tail spine. The tail is raised above the back and stabs forwards and upwards at predators trying to attack them.

Then there are those fishes that

Leopards and other big cats have large teeth and powerful jaws. To kill their prey, they must grip it firmly and pull it to the ground. To do that they must be immensely strong.



Anthony Bannister/Oxford Scientific Films

1,000 metres – the longest recorded dive lasted 1 hour 52 minutes. When the whale came up it was harpooned and killed. It had two sharks in its stomach of a type that are only found on the sea floor – which was more than 3,000 metres at that point.

To survive in a very competitive world, clever eye design can help give animals an edge. Flies have complex compound eyes which are highly developed to distinguish movement and colour. Try swatting a fly and you will see how quick off the mark they are.

Despite their small size, most insects can achieve quite phenomenal speed of flight. For example, the hawk moth can reach speeds of around 25 km/h. Most flies can achieve around a quarter of that speed. And some insects flap their wings at an incredible speed during flight. Some species of midge beat their wings 1,000 times a second.



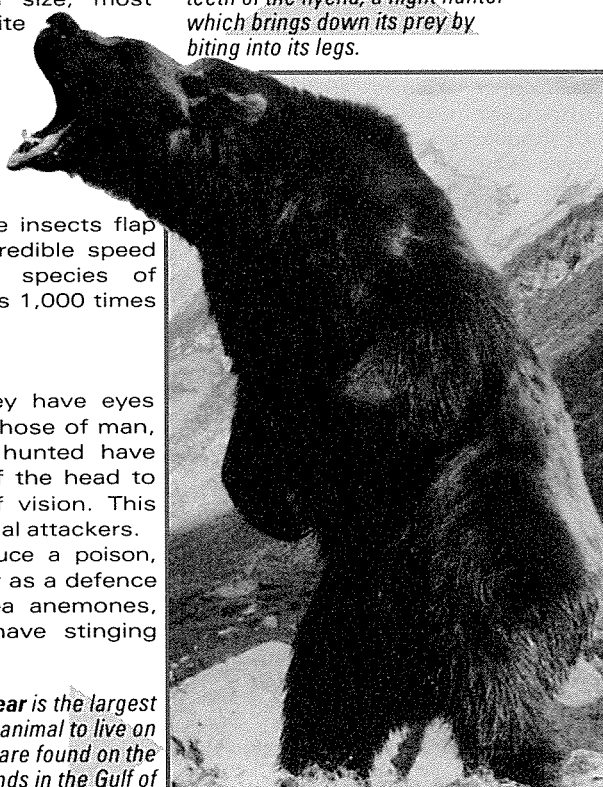
Birds of prey

Birds which hunt prey have eyes in front of them, like those of man, while birds that are hunted have eyes on either side of the head to cover a large field of vision. This helps them see potential attackers.

Many animals produce a poison, either to catch food or as a defence against predators. Sea anemones, jellyfish and corals have stinging



The strong jaw and powerful teeth of the hyena, a night hunter which brings down its prey by biting into its legs.



The Kodiak bear is the largest meat-eating animal to live on land. They are found on the Kodiak islands in the Gulf of Alaska.

can give potential predators an electric shock. The best known is the electric eel, which can jolt its victim with several hundred volts. It also uses this shocking ability to stun smaller fishes as prey.

One of the most remarkable offensive weapons in the marine world is possessed by the archer fish, which swims close to the surface of rivers in its native India

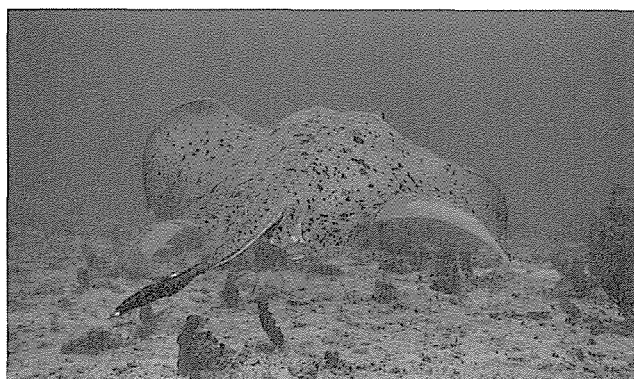


David Cayless/Oxford Scientific Films

Black rhinoceroses face each other with the threat of their huge horns – cones of tightly compacted hair. They fight over territory and females.

and Australia. When it spots potential insect prey on low-hanging tree branches, the fish rises to the surface and spits a jet of water from its mouth which knocks the insect into the river where it is rapidly devoured. The jet effect is achieved with a groove along the fish's mouth. When the tongue is pressed on it

The stingray's tail is covered with sharp spines and coated with venomous slime – which can be fatal to humans. However, it is a defensive, not an offensive weapon and is rarely used. Usually, when disturbed, the ray will swim away.



the result is a narrow tube. By closing the gills, the fish can eject water under pressure through the tube.

The deep-sea angler fish employs a more subtle method to catch its prey. A fishing rod-like fin grows from its back which can bend round in front of the fish's mouth. A fleshy worm-like growth dangles from the end of the fin, which acts as a bait for smaller fish. When the bait is taken, the angler fish strikes before the prey realizes it has been tricked.

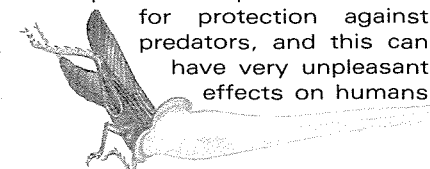
Some marine animals, such as the octopus and cuttlefish, have ink

The lightning tongue of the chameleon can easily catch even a fast moving insect like a locust. Its tongue has a hollow tip – for holding the victim – and is operated by a set of specialized muscles.

sacs. When threatened, these animals discharge the contents of their sac into the water. This produces a black cloud which enables the animal to escape.

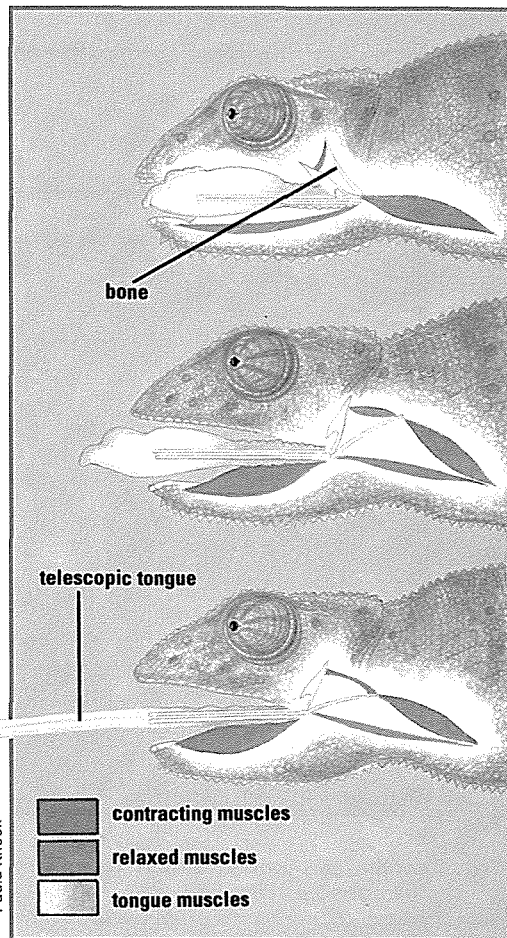
Pincers are a powerful instrument. They are found particularly in crabs and lobsters. Often they are uneven. One pincer may be used for cutting, while the other is more heavily built and is used to crush prey, such as molluscs, which have a tough protective shell. But, if the lobster or crab is attacked, it uses both pincers to defend itself.

Scorpions use a powerful venom for protection against predators, and this can have very unpleasant effects on humans



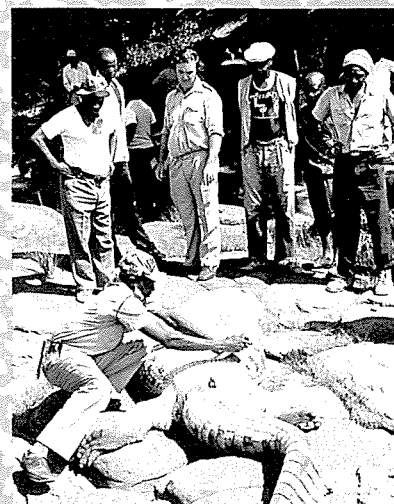
unfortunate enough to come into contact with one. The poison is also used on the insects they hunt for food. But it is just as dangerous to other scorpions, so they have an elaborate courtship dance in order to avoid stinging each other during mating.

Spiders use poisons to subdue their prey and some species, such as the black widow spider, produce such powerful poisons that they can prove lethal to man. Most spiders have a poisonous bite but only a



Paula Knock

EATEN ALIVE



Herwarth Voigtman/Planet Earth Pictures

Gamma/Frank Spooner Pictures

few can harm large animals. Spiders also use silk to catch prey, either in the form of a web, a trip-wire or even a lasso.

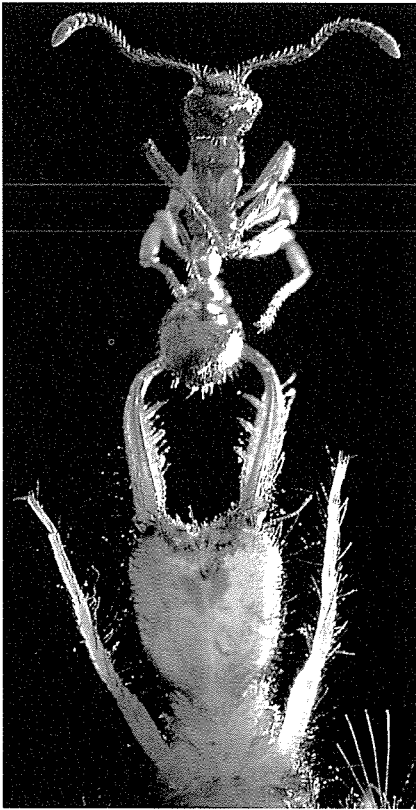
Scorpions and spiders of the desert tend to have very potent venoms. As there is little food, they must be able to quickly kill any prey that they encounter.

Adders, rattlesnakes and cobras inject poison into victims via hollow fangs. The king cobra of south-east Asia is the world's largest species of venomous snake and feeds mainly upon other snakes.

Most snakes have extremely

The crocodile is one of the most dangerous animals in the world. This one, killed by rangers in South Africa's Kruger National Park, is about to have its stomach split open: inside is a partially digested man. Besides attacking prey that is in the water, crocodiles use their hugely powerful tails to sweep animals – including people – off river banks. Once in the river, they drown their prey, then tear it to pieces with their formidable array of teeth, or swallow it whole. This crocodile's stomach had been carrying its human victim for 3 days, and it also had a wart-hog inside.





The ant-lion larva can crush a real ant in its powerful jaws. The ant-lion larva is not really an ant – it is the larva of a separate group of insects called ant-lions.

against any would-be attacker. Lions are the largest of the big cats, standing a metre high. They have powerful jaws and sharp teeth and claws, all of which are useful in tearing the flesh of zebra and antelope, their most common form of prey.

Several species of toads and salamander, including arrow-poison frogs, secrete a defensive poisonous substance on their skin. This has a drastic effect on the mouth linings of predators such as dogs which immediately drop the animal and salivate in large quantities to get rid of the terrible taste. Indians in Columbia have used the secretion of the Variable Tree Frog for poisoning the tips of their hunting arrows.

Stink glands

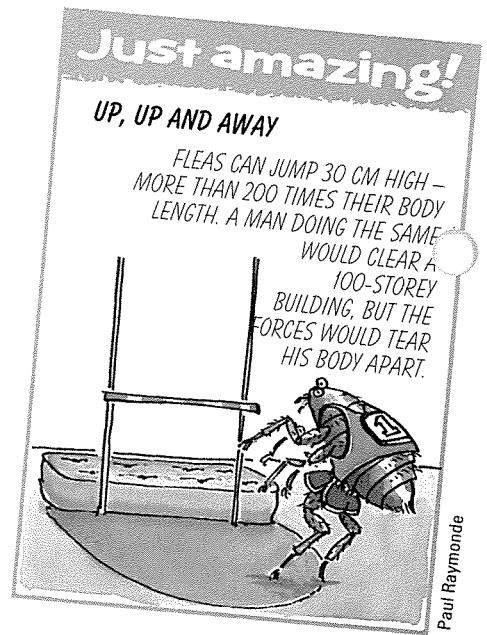
The North American skunk has a highly effective defence mechanism in the form of a powerful smell. The skunk has a pair of stink glands by the tail that shoot a fine spray of golden yellow liquid over several metres. This has a smell strong enough to put off all but the most determined predator.

However, the world's smelliest animal is the African zorilla. The nauseating fluid from its anal glands can be smelt 1.6 km away and a zorilla can keep a pack of lions at bay for several hours.

Some animals have developed

mobile jaw-bones which, allied to a stretchable throat skin, enable them to swallow prey much wider than the size of their own head.

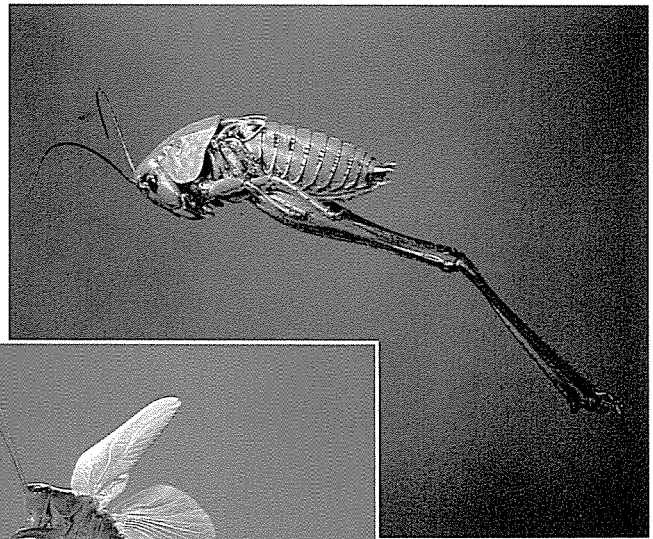
The keen-eyed kingfisher swoops with devastating accuracy into rivers where it rarely misses the fish that are its target. Once the fish is grabbed in the kingfisher's strong beak, the wings are used to launch



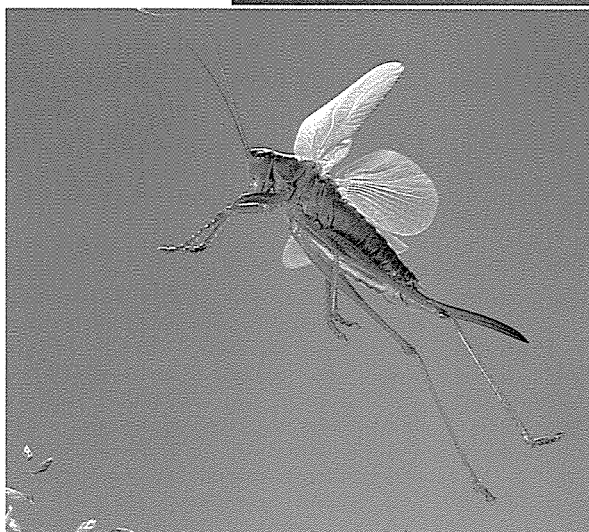
their teeth into powerful weapons. The wild boar's canine teeth have evolved into tusks with immense gripping power. The razor teeth of a shark have long been known to tear apart human flesh. Their teeth are so sharp that they sometimes tear fishing nets to get at the catch.

Jaw power is not just associated with large animals. The young desert-living ant-lion has very powerful pincer-like jaws which it uses to burrow a hole into the sands. When its prey – ants or spiders – disturb the sand on the hole's edges, the ant-lion reacts by flicking a grain of sand from the top of its head towards its target, knocking the prey into the pit where it is quickly eaten.

The flea's hindlegs are specifically designed so that it can jump quickly from host to host, in search of fresh blood to drink.



ZEFA



The grasshopper's powerful back legs launch it into the air. Its large wings and wing cases are used to give it extra distance in flight.

it out of the water. The kingfisher then returns to a nearby branch where the fish is swallowed whole, always head first.

All members of the cat family, which includes lions and tigers, have claws that can be used offensively and defensively. The tiger has one of the most developed sets of claws that are extremely sharp and strong and are used to both grip their prey and defend the tiger



ANIMAL



STRONGHOLDS

-  HUGE COLONIES
-  SAFETY FIRST
-  COMMUNES

HUMANS ARE NOT ALONE IN feeling a need to build secure homes. Animals choose homes and nests with safety uppermost in their minds.

They need to bring up young and to sleep without fear of attack from predators, and some animals prefer the extra protection of living in a community.

Most ants, termites, bees and

***The golden eagle** builds its nest high up in the mountains or in trees to keep the chicks safe from natural predators – and from humans, too.*

***The hermit crab** inhabits any shell it can find and is soon covered by sea anemones. They feed on the crab's leftovers and protect the crab.*

wasps are social insects that live in colonies in large numbers. There are estimated to be more than one thousand million million ants on Earth. They produce wings when they reproduce and swarm out of the colony for a short period called a nuptial flight. After mating, the female makes a small chamber in which she lays her eggs. The first larvae develop into wingless worker ants, whose job is to forage for themselves and for the queen.

Ant slaves

In some species, soldier ants are produced to build and defend the colony. In others, worker slaves of another species are captured to do the work.

In some dry areas around the Mediterranean, harvest ants keep seeds in underground storehouses so that they will have a food supply in times of shortage. Most ant colonies are just below the surface, but leaf-cutting ants burrow as deep as 6 metres down, cultivating underground fungus 'gardens' using chewed-up leaves as soil.

Honey bees

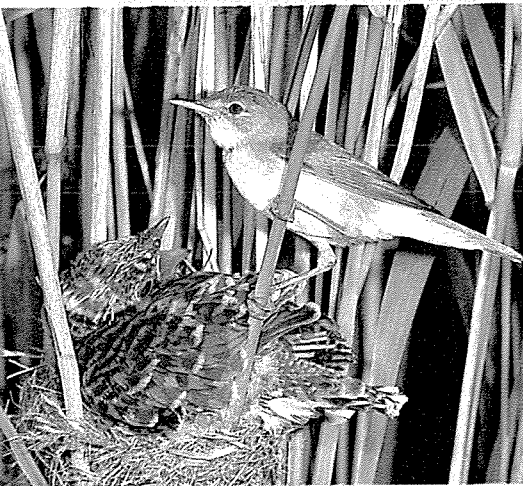
Bees and wasps are other insects that usually live communally. One of the most remarkable social systems belongs to the honey bee, which has been domesticated for centuries. A colony contains a large queen, smaller drones and worker bees. Each has specific work to do and is dependent on the others for survival. The queen and the workers grow from identically fertilized eggs, but the egg and larva of the queen develops in a larger cell. She is also fed on a special diet of 'royal jelly' produced by the worker bees.

The drones are male bees that are formed from unfertilized eggs. They are larger than workers but are shorter and stockier than the queen. They have no sting and their function is solely to mate with virgin

JLG Grande/Bruce Coleman Ltd



MERCILESS SQUATTER



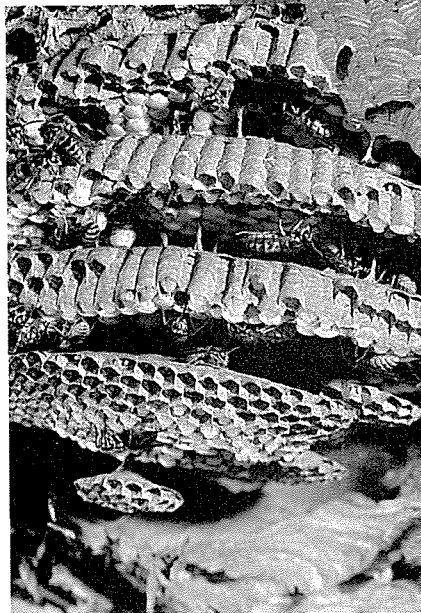
Roger Wilmshurst/Bruce Coleman Ltd

The cuckoo is a uniquely parasitic bird. The female lays her eggs in the nests of much smaller birds, such as the reed warbler (above), replacing one of the host's eggs with one of her own. Birds will often fight off adult cuckoos to prevent them laying eggs, but once laid, they are always hatched and fed. The young cuckoo usually hatches out before the host's eggs and it soon goes about pushing the others out of the nest. The blind, naked chick holds the egg on its back between its wings and instinctively pushes itself backwards up the nest wall until it tips the egg over the edge. The young cuckoo soon fills the nest itself, often dwarfing the host parents who try to satisfy its voracious appetite. After three to five weeks, it leaves the nest.

queens, in mid-air. Drones are normally present from late April until August, after which any that have survived the summer are forced out of the hive by the workers.

The workers run and organize the colony. They secrete wax to build the comb, gather stores of pollen

Hornets make their nests out of papier-mâché. They chew up rotten wood to make a sort of cardboard, arranged into hexagonal cells, which contain the larvae (below). The nest is wrapped in more 'paper'.



Alastair MacEwen/Oxford Scientific Films

and nectar, nurse the young and ventilate and guard the colony. They are armed with a barbed sting that they usually only use to defend the colony. When used on humans, the sting cannot be withdrawn because of the barb. It is, therefore, torn from the bee, resulting in its death.

Short, hard life

Worker bees wear themselves out quickly — they only live for about six weeks. Their first job is to clean the cells and act as nurses to the larvae, feeding them and keeping them warm. After about two weeks, their duties change to collecting nectar and pollen; older bees can be recognized by their ragged wings that get worn out because of the heavy loads they carry.

It is not only insects that choose a social life — many mammals prefer communal living, too. The naked mole rat, which actually has a few hairs, is blind and has no exterior ears. Like many small mammals, it excavates a mass of tunnels to form a colony and this contains a reproducing queen, mating males, and nurses.

Working together

The racoon-like meerkat remains a prime example of successful communal living. It lives in the inhospitable Kalahari desert and each member of the colony takes on specific duties to protect each other. These

include sentry duty, childminding, hunting, teaching and so on. The colony can comprise up to 20 members, who sleep in a network of burrows.

Within days of the young being born, the mother returns to hunting and they are looked after by a rota of baby sitters. Adults bring back food for them at this stage, but the young soon have to fend for themselves and bring back food for the next litter.

The beaver forms its lodge by burrowing into the bank. It piles branches up on the lodge, then dams the stream to raise the water and form an island.

lodge built up with branches

water level rises when dam is built, forming an island

beaver burrows into bank

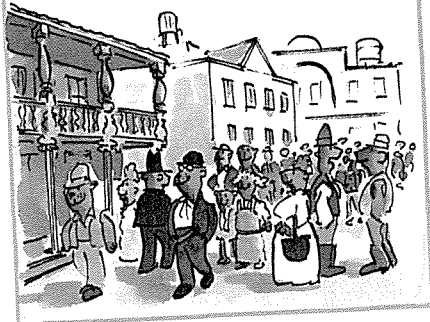
Mark Franklin

Beavers live in family groups, constructing a complicated island home called a lodge. They first dig a burrow in the bank of a stream, piling branches over the entrance to form a lodge. Then a dam is constructed across the stream to raise the water level and form an island, which gives the family total security from enemies.

Just amazing!

CROWDED COLONY

THE LARGEST ANIMAL 'TOWN' EVER WAS A COLONY OF BLACK-TAILED PRAIRIE DOGS DISCOVERED IN 1901, IN TEXAS. TWICE THE SIZE OF BELGIUM, IT HAD A POPULATION OF 400 MILLION!



Paul Raymonde





Jean Michel Labat/Ardea London

Uncovered meat attracts flies. These lay white clusters of eggs, which hatch into hungry maggots.

REEP-CRAWLIES

-  BED BUGS
-  MICROFUNGI
-  COCKROACHES

MICROSCOPIC LIFEFORMS too small to be seen are all around us, even in the cleanest home. Most of them do us little or no harm and many are important – even vital – to everyday life.

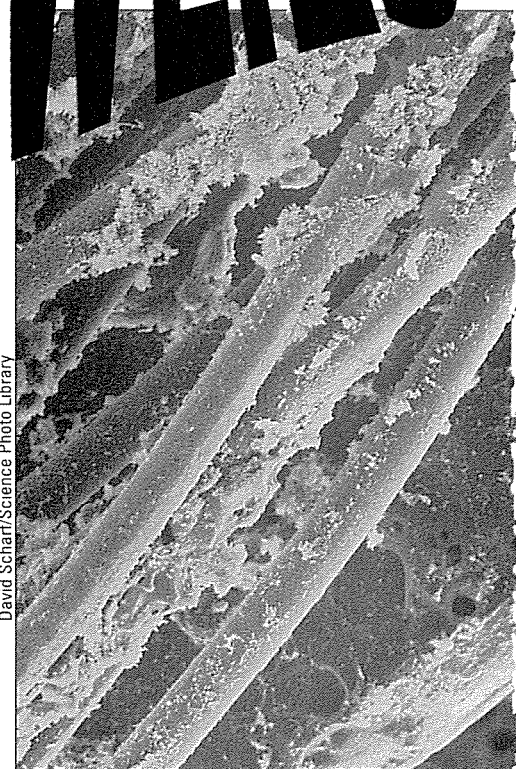
The smallest microscopic life-forms are the viruses, bacteria and fungi. Viruses multiply only in living cells, so their effects are usually seen as a visible disease – in household plants that develop coloured spots or rings on the leaves for instance. In plants that are badly affected, there may be no other course but to destroy them, because such diseases cannot be treated effectively.

Certain viruses, however, are useful because they attack the cells

of bacteria and fungi that cause disease. Those that attack the cells of microbes are called bacteriophages (or phages for short). Some phages have a simple rod shape; others are like miniature spaceships.

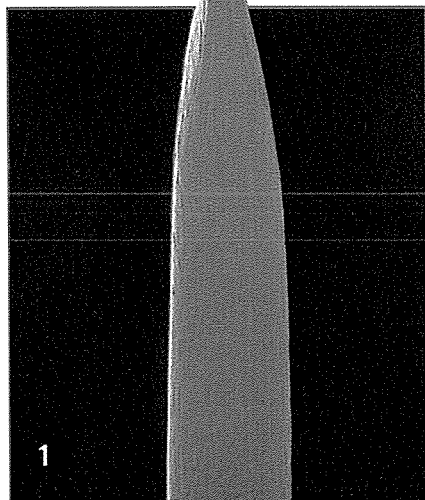
Bacteria are living cells. They are bigger than viruses, but are so small that a million or more of them may live on the point of a pin. They become visible to the naked eye only when they have formed a colony of many millions, appearing usually as a jelly-like speck.

The strands of a used kitchen scourer, magnified 200 times through an electron microscope, are clearly covered with clumps of rod-shaped bacteria.

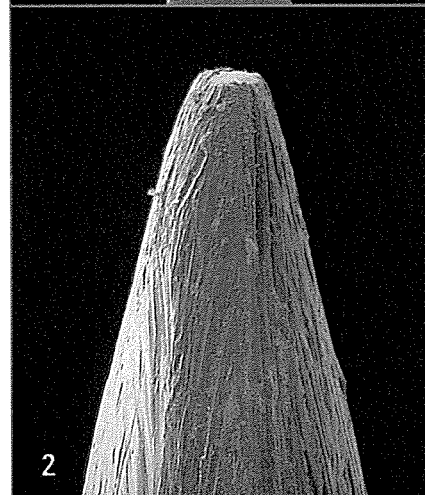


David Scharf/Science Photo Library

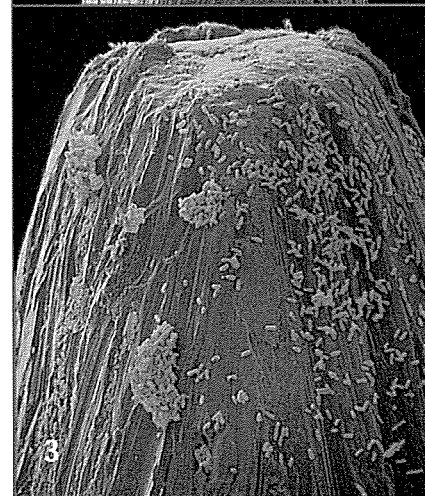




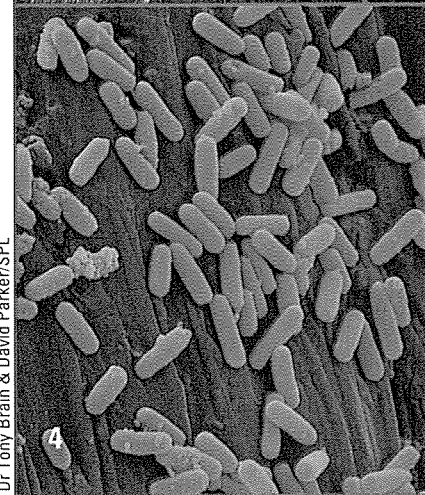
1



2



3



4

Bacteria are everywhere but normally unseen. As the point of a household pin is magnified from x7 (1), to x35 (2), x175 (3) and x875 (4), bacilli are revealed.

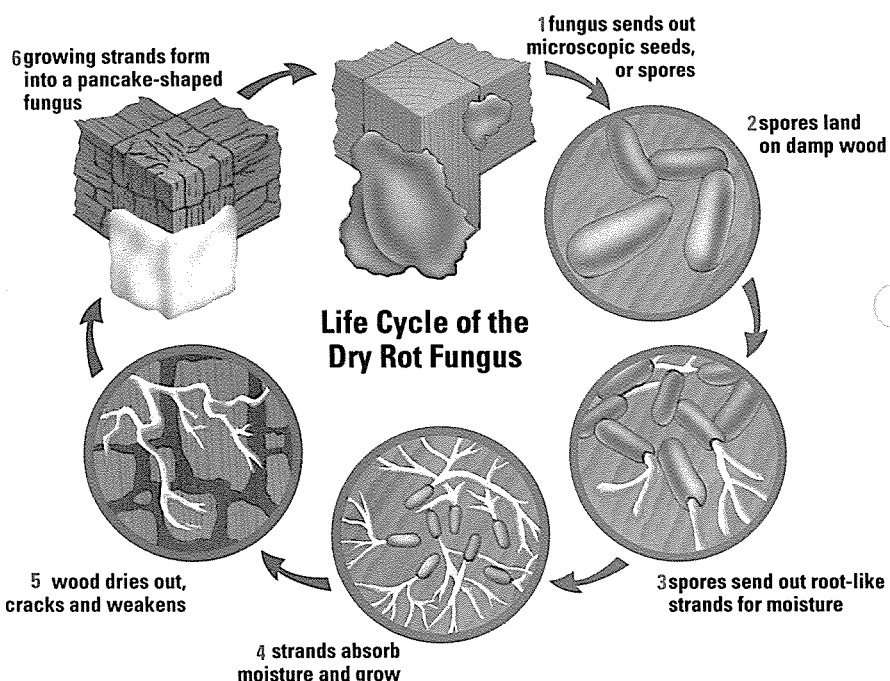
WINGLESS WRIGGLER

A flat silvery-grey creature moving with a wriggling motion in the empty bathtub is likely to be a silverfish. It is usually classed with the insects – although it has no wings. The silver-fish is so primitive that it, and its relative the firebrat can be regarded as a 'living fossil'. These harmless little wrigglers eat the starchy paste in books and clothes.

John Howard/Science Photo Library



Dry rot is caused by a fungus. The air-borne spores (below) settle on damp wood, growing into a pancake-shaped plant, which then emits fresh spores.



In the home, huge colonies of bacteria can sometimes be seen on stale fruit and vegetables. Once established, they dissolve the pectin that holds the cells together and quickly reduce the fruit to a slimy mess.

Rotten feast

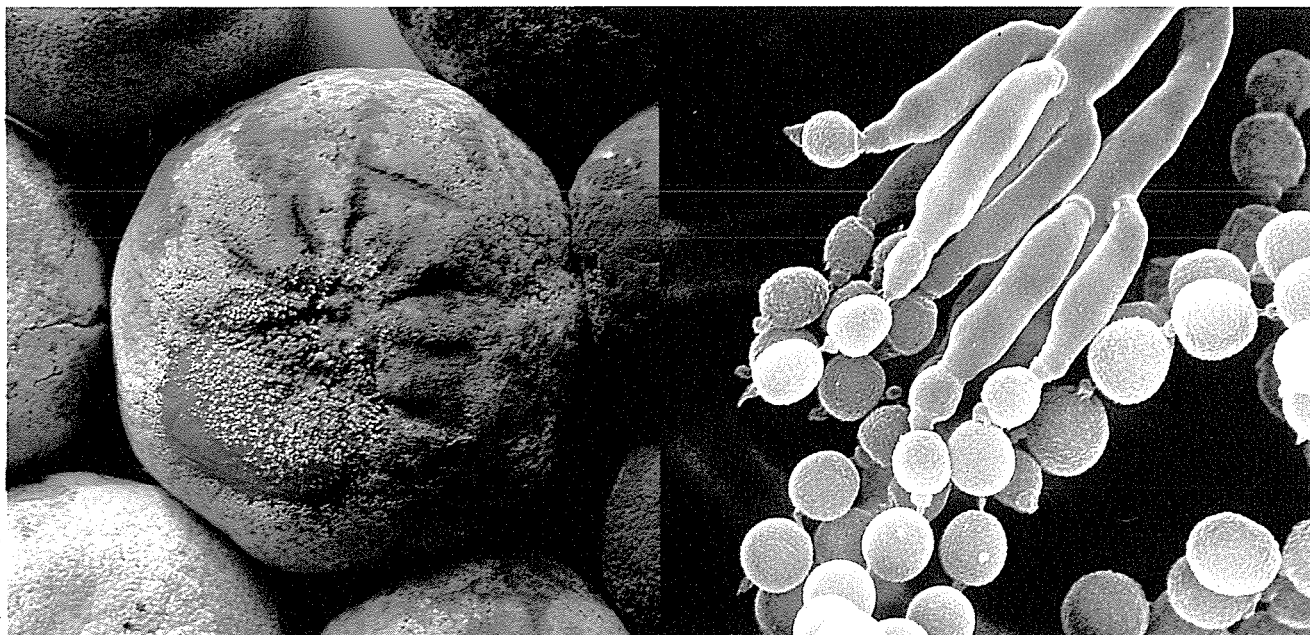
Meat is also attractive food to bacteria. Often a bluish colour is the first sign that they are feeding and multiplying, and the food is spoilt long before the foul smell of decay can be detected.

Many foods contain bacteria within them – not just on the surface. If they are kept refrigerated at low temperatures, the growth of these bacteria is greatly reduced. If the food is left out of the refrigerator or freezer, however, the bacteria feed, multiply rapidly in the warmth and spoil the food.

Even handling a piece of meat or other food will add more bacteria to it, because we all have bacteria inside our bodies and on our skins. Usually, however, these are not the bacteria that cause meat to go rotten. In fact, the bacteria on our skin are among the many 'good bugs', because they feed on harmful ones that would otherwise colonize our bodies.

Humans produce large numbers of bacteria. Each gramme of faeces contains 1,000 million or more bacterial cells, which are usually harmless once they have been flushed away into the sewers. Lavatory cleaners that 'kill all known germs' are little more effective than the copper coins they cost, because copper is a powerful bactericide. Pennies in the loo, however, would stain it and leave an





unpleasant odour.

Microfungi are among the most numerous of all the microbes in the home – and some are harmful. They are related to the larger fungi, such as mushrooms and toadstools but, as their name implies, they are too small to be seen except through a microscope.

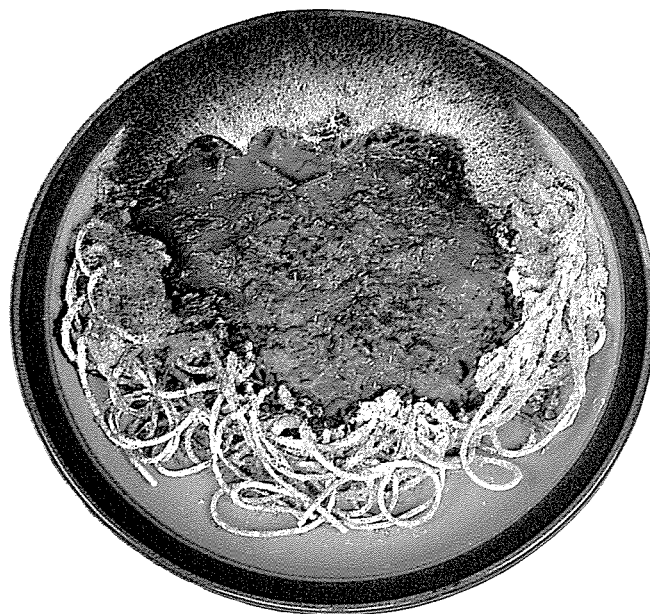
Bad bugs

Microfungi's spores – tiny cells by which they reproduce – float about in the air in vast numbers. We breathe in many of these spores, but the bacteria in our bodies engulf and destroy them before they can cause us harm.

The presence of microfungi can be seen if food, such as bread, is left out in the open to go stale. Within a few days, spores begin to grow on it to form a green or black mould. These spores are mostly of the *penicillium* and *aspergillus* types of microfungus, the two com-

Rotting fruit is a bluish-green (left) because of the penicillium mould (from which the antibiotic penicillin is made), growing on it. The mould is harmful if eaten. The microscopic spores can be quite clearly seen at x750 magnification.

Stale food is a rich source of nourishment for fungi, as well as maggots, both of which serve a useful purpose – they help to break down rotting matter as Nature's very own waste disposal service.

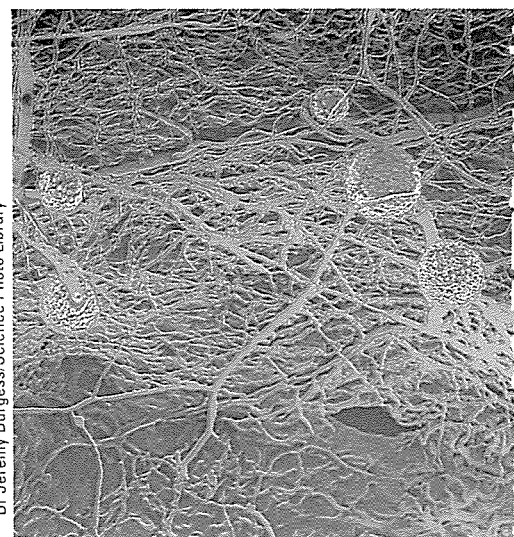


monest of all air-borne moulds.

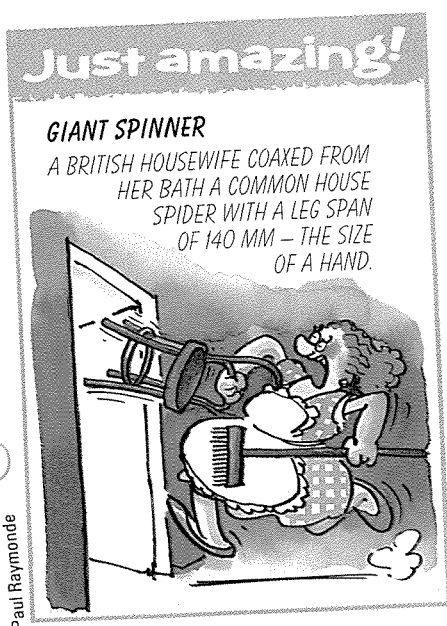
Some species of *penicillium* mould are 'good bugs' because they give penicillin – the important antibiotic drug. Some *aspergillus* moulds produce chemicals that can cause cancer, but only rarely are humans at risk from them.

The dry-rot fungus, which destroys timber, is a serious household microbe. The fungus needs damp wood at first, but later it gets moisture from the air. It sends out microscopic fungal threads, which can penetrate masonry and bricks to reach, and rot, dry timber – hence the name dry rot. There are chemicals that kill dry rot for, left unchecked, it can weaken the structure and bring it down.

Less serious, but highly unsightly, are various kinds of fungi that cause patches of jelly-like growths on damp walls. These, unlike dry rot, can be killed simply by drying the walls and so cutting off the



Mould growing on a slice of bread – as seen, magnified 30 times, in a false-colour photograph.



Just amazing!

GIANT SPINNER

A BRITISH HOUSEWIFE COAXED FROM HER BATH A COMMON HOUSE SPIDER WITH A LEG SPAN OF 140 MM – THE SIZE OF A HAND.



meal and adult bugs have been known to survive more than a year without food.

House pests

Clothes moth caterpillars used to be a menace in clothes cupboards when garments were mostly made of wool and cotton. Today, these pests are still a problem, even though most cloth contains large amounts of inedible, synthetic fibres.

Furniture beetle, or woodworm, burrows through wood, reducing it to a network of holes and trails of powder. All structural timber is treated with an insecticide to control woodworm. Some items of furniture, however, are untreated, and the pest is usually introduced into the home in old or antique furniture.

Woodworm only attack old wood – soft wood that is at least 20 years old and hard wood that is at least 60 years old.

A woodworm beetle crawls out of a hole in a piece of furniture. Although it is a domestic pest, in the wild it aids the decomposition of dead trees.

A cheese mite – quite common in kitchens – crawls through strands of penicillium fungus as it feeds on mouldy cheese.

supply of moisture the fungi need.

Chemical sprays used to kill insect and microbial pests might leave residues on fruit and vegetables that could be toxic to humans as well as to the bugs they are intended to destroy. A less-harmful method of control is to breed food plants to have greater resistance to pests and diseases.

Compared with microbes, insects

Mice may be the most visible of household guests but they are also the most harmless – living of scraps of food dropped on the floor. This family has made its home in a cavity wall.

Swollen after its meal of human blood, a bed bug (magnified x15) will not need to eat again for several days.

infest our homes in much smaller numbers, at least in cooler countries. In the tropics, hordes of termites – ant-like creatures – can bring a house down by destroying its timber. Living in the gut of termites are single-celled organisms called flagellates, which produce enzymes that digest the wood.

Cockroaches may infest homes in which food is dropped and left in concealed spaces. Once they are established in numbers, fumigation

with poison gas is the most effective means of killing them. Creatures such as beetles, silverfish, spiders and centipedes, however, rarely reach plague numbers and are not dangerous. Fleas can infest both humans and animals and are equally at home on either dirty or clean hosts. They are killed by special sprays.

Bed bugs are still a problem in some badly kept hotels. These are fat insects which hide during the day – in bed clothing, mattresses, bed frames or behind wallpaper – then creep out at night to feed on blood via their piercing mouthparts. They may take several days to digest a

Liz & Tony Bonford/Ardea London

Dr Jeremy Burgess/Science Photo Library

Dr Tony Brain & David Parker/SPL

Dr Tony Brain/Science Photo Library



A lone hunter, the leopard usually operates at night. It often drags its kill up trees away from scavengers.



Jonathan Scott/Planet Earth Pictures

ANIMALS OF PREY

THE NATURAL WORLD IS A violent place. In order to survive, many wild animals prey on and eat other living creatures, and have developed a variety of ingenious weapons to help them do so.

Of all the weapons and tools used by animals, teeth and claws are probably the most obvious. Carnivores – flesh-eating mammals – have an impressive array of teeth.

The incisors at the front of the jaw help to cut or tear pieces of flesh from a carcass. The long, pointed canine or 'dog' teeth are designed for stabbing and holding on to prey. Further back are sharp-edged carnassial teeth – designed for slicing through flesh. In addition there are molars and premolars that can grind up bone.

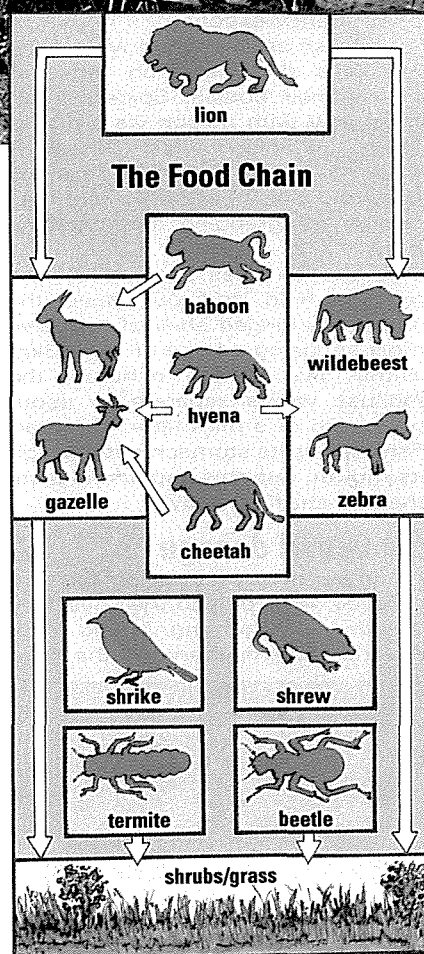
The incisor teeth of a vampire bat are so razor-sharp that they can

lacerate the skin of their prey – cattle, horses, domestic animals, poultry and man – using virtually no pressure. The bat's saliva contains an anti-coagulant (that stops blood clotting) enabling the bat to then lap up the flowing blood with its grooved tongue.

Overgrown teeth

Other mammals also use their teeth as weapons. A rat, for example, can defend itself with a nasty bite from its incisors, which, like those of other rodents, grow continually as they are worn down by gnawing. An elephant's tusks are, in fact, huge, overgrown incisor teeth, and a hippopotamus fights with tusks formed from its incisor and canine teeth.

Potential victims of predators have evolved their own weapons for defending themselves against attack.



John Houghton

In the ecosystem of the East African plains, the lion – a top predator – feeds on large herbivores (plant-eating animals), such as the zebra or wildebeest.



KILLER WORMS

Natural methods of pest control are increasingly being seen as preferable alternatives to using potentially toxic chemical pesticides. To this end scientists are attempting to find the perfect breed of nematode worms that have been found to kill insect larvae living in soil. These colourless worms carry colonies of bacteria in their mouths. They invade a group of insect larvae and release this bacteria into the surrounding soil. The bacteria kills the young insects and multiplies rapidly as it destroys their body tissues. The nematode worms then return to feed on the increased numbers of bacteria.

Armadillos and anteaters, for example, can defend themselves fiercely with their claws. An anteater's claws are so huge that it has to walk on its knuckles.

Poisonous stings

Invertebrates (animals with no backbone) include about 97 per cent of all living animals. Predatory invertebrates rarely have teeth or claws, but are armed with a variety of different weapons.

Jellyfish are equipped with stinging cells that hang on tentacles below their bodies. Spiders inject their prey with poison via a pair of fangs on their heads. Scorpions have poison stings in their tails and powerful pincers at the front of their bodies for grabbing and crushing prey.

A starfish uses sucker-like tube feet to hold and pull open the two-piece hinged shell of a bivalve mollusc, using a force of up to 3kg. Within five to ten minutes, the mollusc valves separate by about one-tenth of a millimetre. The starfish throws its stomach out through its mouth, into this gap and digests the soft shellfish body.

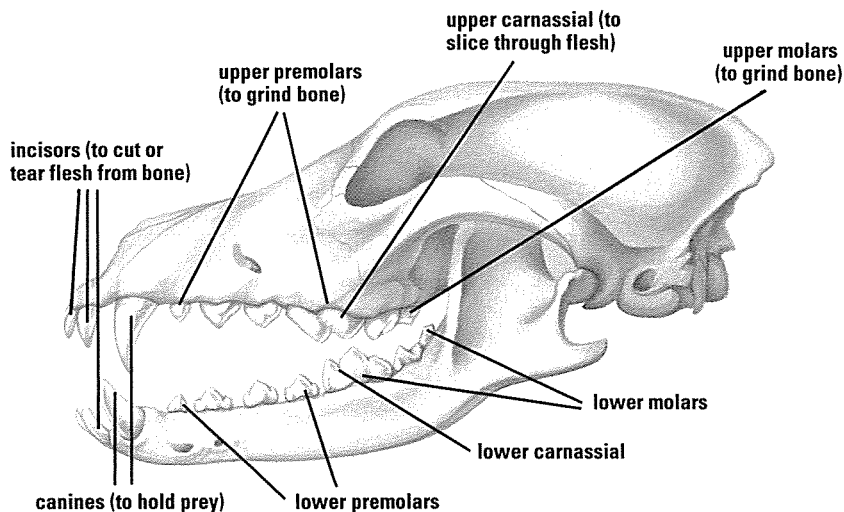
Lethal dosage

A number of insects use poison as a defence. Ants defend their nests by injecting or squirting formic acid. Several butterflies and moths have

poisons in their bodies to deter would-be predators. Predators are warned of this danger by the bright coloration of their prey.

A number of fishes have poison spines, and several frogs and toads

The teeth of the dog family have especially long canines for holding on to prey. All dogs have elongated jaws with 42-44 teeth.



Mark Iley



Bruce Coleman Ltd

The osprey specializes in catching fish. It dives from a height of 25 metres, entering the water claws first – ready to grasp – carries its meal off and rips it apart with its sharp beak.

The Nile crocodile occupies a position at the top of the food chain – being challenged only by man. A male can reach five metres long when fully grown. Crocodile teeth are conical and more suited to holding than to cutting flesh. A crocodile will grip its victim and spin its own body violently until a limb or chunk of flesh tears free.

produce poisons. In northern Australia, cane toads, an introduced species that has now become a major pest, regularly cause the deaths of domestic cats and dogs that eat them.

On the defensive

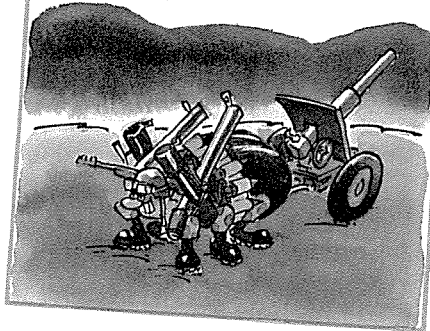
Other animals have equally effective defence weapons. The spines of a hedgehog make it virtually unassailable when it curls itself into a ball. A porcupine's quills may become embedded in the flesh of a would-be predator and the result is very painful.

The skunk, too, has little to fear from an enemy: it simply turns around and fires a nauseating liquid directly into its attacker's eyes, causing irritation and sometimes temporary blindness. The skunk can hit its target with incredible accuracy from a distance of up to 3.5 metres. Over much of the USA, the skunk is the chief carrier of rabies.

Just amazing!

WHO GOES THERE?

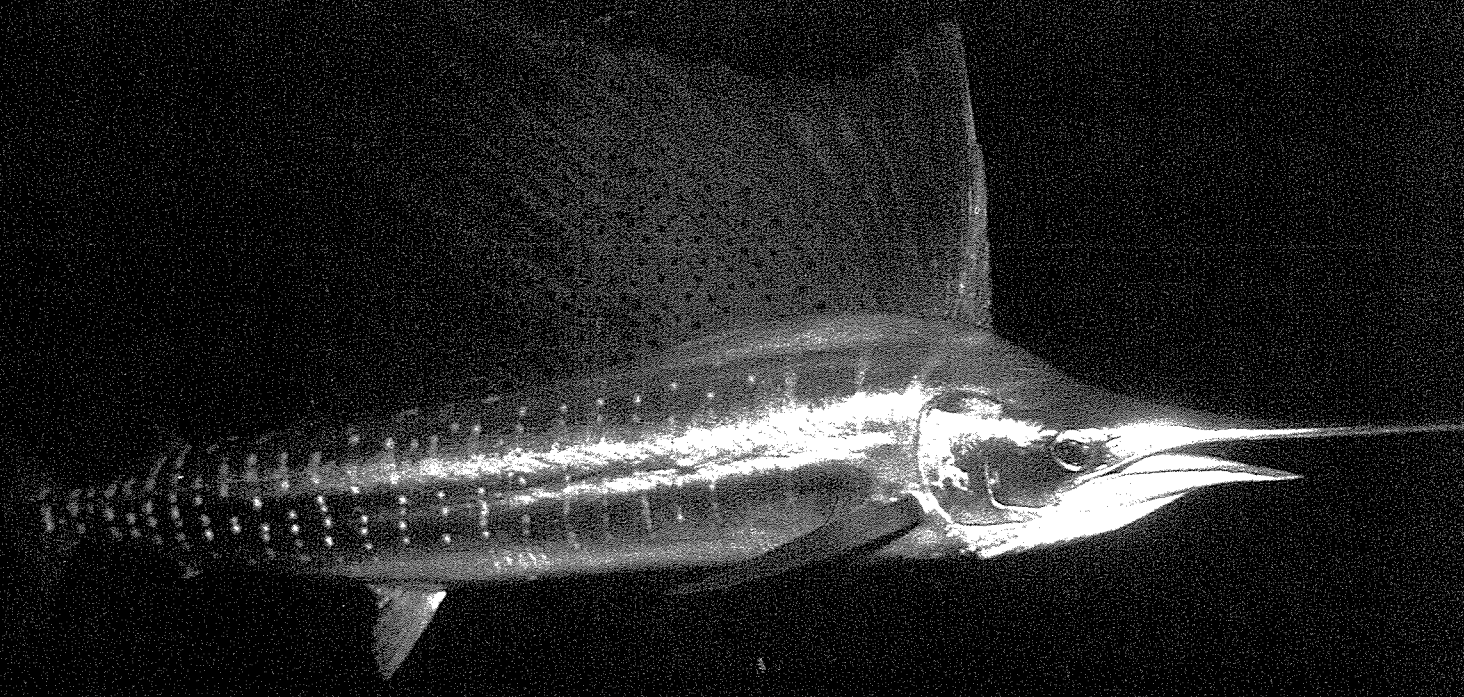
THE BOMBARDIER BEETLE'S DEFENSIVE WEAPON IS TO FIRE PELLETS OF CHEMICAL FLUID. THE FLUID EVAPORATES SO QUICKLY IN THE AIR THAT THESE 'BOMBS' EXPLODE WITH A LOUD BANG.



Paul Raymonde



ANIMALS ON THE MOVE



THE FASTEST THING ON FOUR legs is the cheetah – in just two seconds it can accelerate from zero to 72 km per hour, reaching a top speed of about 115 km per hour for 500 metres at a stretch.

Being quick has obvious advantages if you rely on catching other animals for food. For this reason, predators rank among the fastest creatures on earth. Even a lion, which is several times heavier than a cheetah, can reach a top speed of 65 km per hour. This is slightly better than a greyhound, and only a little slower than a thoroughbred

racehorse.

Predators do not have it all their own way, though. Many of their prey run nearly as fast. The African gazelle, for instance, can hit 80 km per hour and sustain this speed for longer than any cat.

Sprinters

Fastest of all prey animals is the North American pronghorn antelope. This has been measured at 88 km per hour in short bursts and at a steady 56 km per hour over a distance as great as 6 km. Plant-eating animals may lack the deadly sprint of the swiftest predators, but

The sailfish grows to a length of 3.5 metres. Its slender, streamlined build enables it to slice through the water at up to 109 km per hour.

they compensate by having superior stamina.

Undisputed world speed record-holder in the animal kingdom is the peregrine falcon. In level flight it could just about keep up with a cheetah moving at top speed. But in a sudden dive, the peregrine falcon can swoop on to its prey at an astonishing 360 km per hour. Another aerial speedster, the spinetail swift, manages 170 km per hour during its spectacular courtship displays.

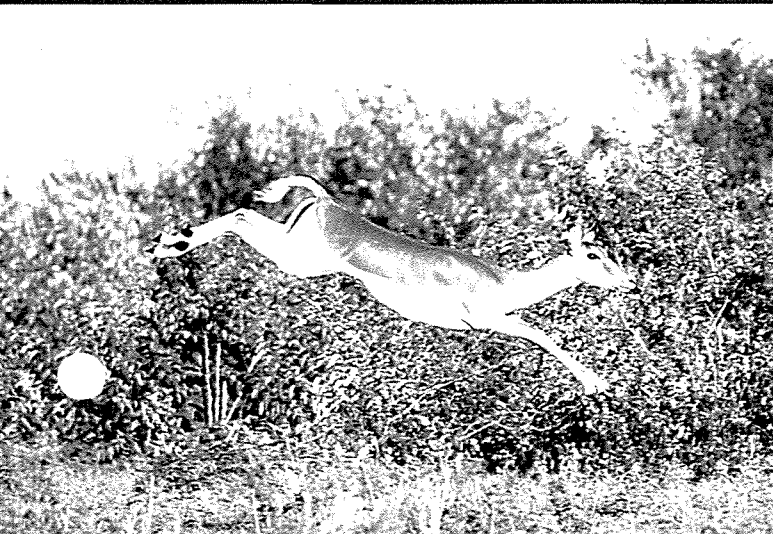
High-speed fish

Because water is 800 times more dense than air, it is much harder for creatures to swim very rapidly. Even so, the sailfish would leave most speedboats standing at its peak of 109 km per hour, while the tuna is only marginally slower. Powerful muscles, swept-back fins, and streamlined bodies combine to cut the resistance of high-speed fish as they move through the water.

Streamlined swoop

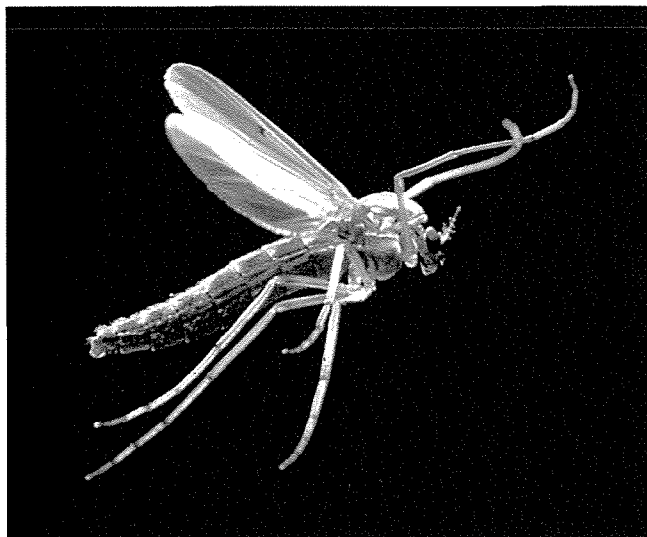
Long narrow wings, special flight feathers and a sleek outline do the same for the peregrine falcon and the swift in the air.

An impala – a species of antelope found in the woodlands of central and southern Africa – has to move fast to avoid swift-footed predators. Adults can reach an estimated speed of 80 km per hour in short bursts. Impala lambs are not so fast – half are caught by predators in the first few weeks of their life.



In the case of fast land animals, it is muscle power teamed with a lightweight body frame that accounts for the creature's tremendous speed. When a member of the big cat family runs, the heavily muscled hind legs provide the thrust that powers each bound

some animals are capable of astonishingly swift actions. Hummingbirds, for instance, can beat their wings up to 60 times a second – the source of their low-pitched buzzing. The Horned sungem of South America manages 90 wing-beats per second, but even this pales into



Octopuses can change their colour and markings in as little as 1 second (for some species), either for camouflage or to frighten away predators.

Midges (tiny flies) beat their wings at a phenomenal rate of up to 1000 per second. They far outstrip humming birds who achieve 60 beats per second as they hover.

– including the final leap on to the prey. It is on record that a tiger once made a single leap of an incredible 5.6 metres from the ground to pull a man from a tree.

Even though they cannot move their whole bodies especially fast,

insignificance compared with the 1,050 wing-beats per second attained by a certain species of midge. The muscle movements of this insect are the fastest ever measured.

A common strategy of many

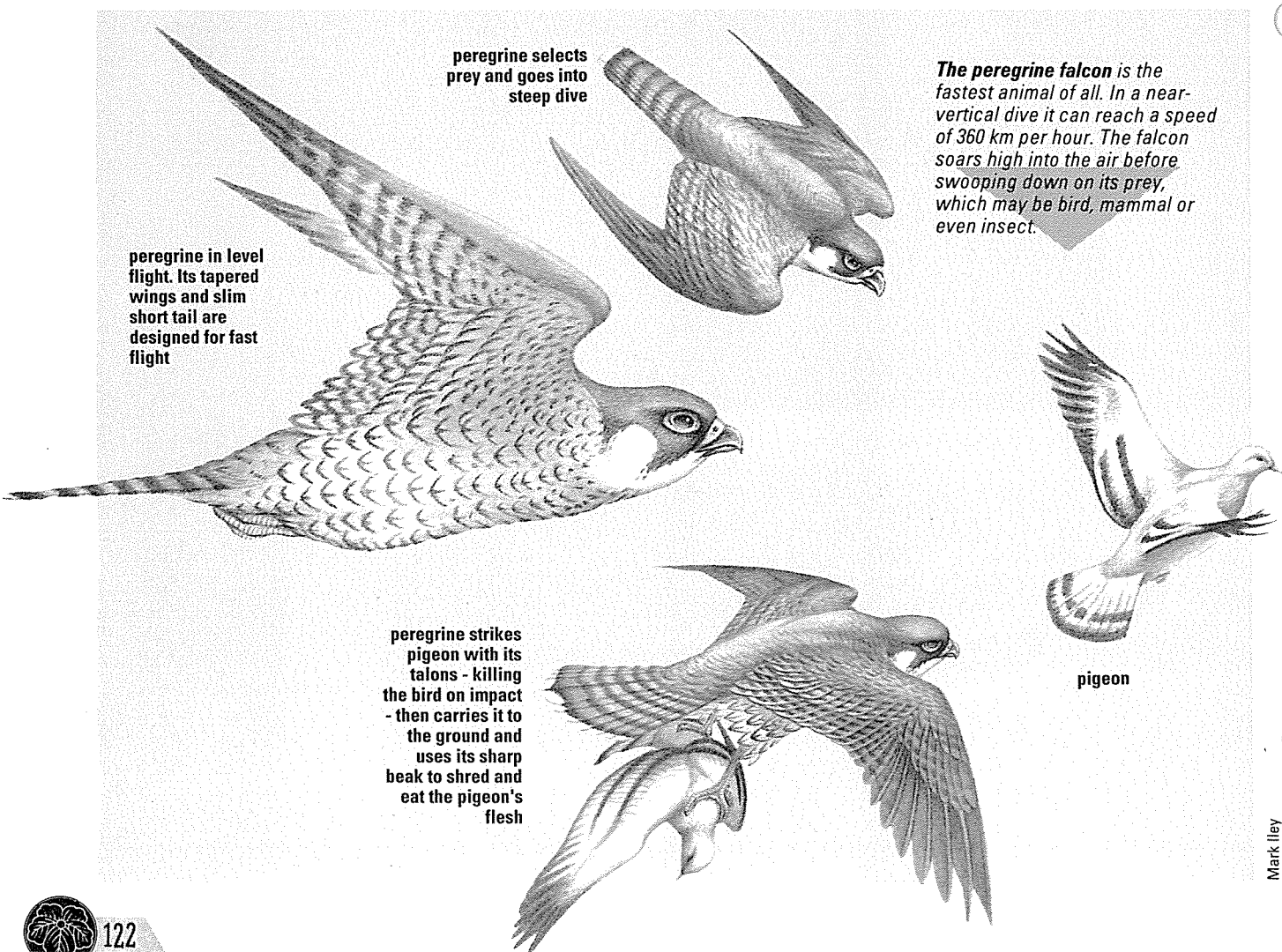


Ron Taylor/Ardea London

predators is to lie still until a prey comes along, then strike suddenly at lightning speed. Angler fish remain motionless while dangling a lure formed from the first ray of their dorsal fin. When a creature approaches and mistakes the lure for a scrap of food, the angler opens its jaws wide, then snaps them shut again – capturing the unfortunate prey inside in less than one twentieth of a second!

Lightning strikes

Chameleons also rely on surprise attack to catch insects. A special set of muscles in the chameleon's



peregrine in level flight. Its tapered wings and slim short tail are designed for fast flight

peregrine selects prey and goes into steep dive

The peregrine falcon is the fastest animal of all. In a near-vertical dive it can reach a speed of 360 km per hour. The falcon soars high into the air before swooping down on its prey, which may be bird, mammal or even insect.

peregrine strikes pigeon with its talons - killing the bird on impact - then carries it to the ground and uses its sharp beak to shred and eat the pigeon's flesh

pigeon

Mark Iley



mouth can shoot out the tongue so quickly that it can only be seen properly on slow-motion film. Since the tongue has a sticky tip that prevents the insect from escaping, it can be pulled back in and folded up at a more leisurely rate.

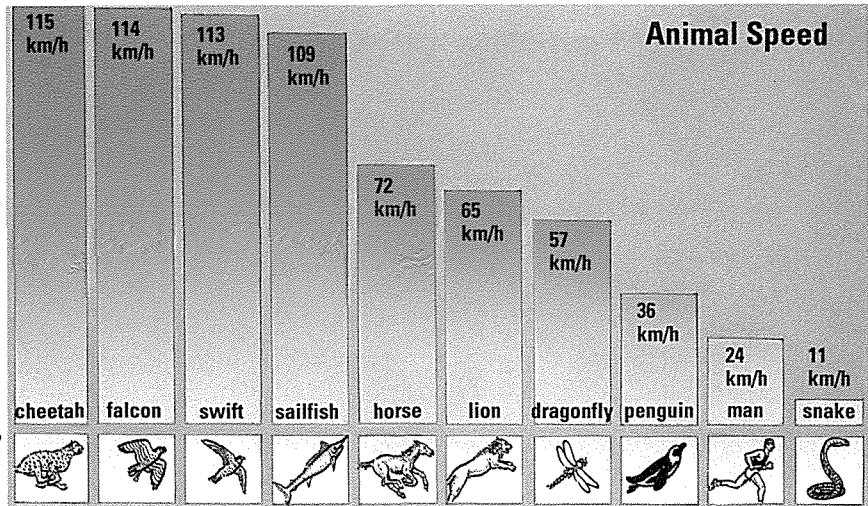
Quick change

Chameleons are also speedy in another way. Some can completely change their colour in about two minutes, making them one of nature's most talented camouflage experts. Even faster colour changes, however, are effected by cephalopods – octopus, squid, and cuttlefish. When afraid or alarmed, these soft-bodied creatures can go from one colour to another in just one second!

As a final escape measure, cephalopods can switch to jet power for a high-speed getaway. They do this by squirting water at great pressure out of a nozzle in their bodies. Squid, for instance, can propel themselves so quickly in this way that they may shoot out of the water and glide for over 30 metres through the air!

Metabolism

There is also a relationship between the speed of a creature's metabolism – how quickly its internal body processes work – and its lifespan. Two of the slowest moving animals in the world, with very slow metabolisms, are the giant Galapagos



tortoise and the quahog ocean clam; they are also among the most long-lived – quahogs may survive to be 200 years old.

A large, normally plodding animal like an elephant, will live much longer than a small, nervous crea-

metabolism. (On average an animal breathes once every 3.9 heartbeats.) The shrew lives its life about 30 times faster than the elephant, experiencing a much greater number of sleeping and activity periods in every 24-hour day.



A mallard duck launches itself into the air with a powerful whirring of wings. Once airborne, it may reach a speed of 100 km per hour. In the water, the duck's webbed feet act as paddles, propelling it along.

NATURAL SLOTH



Manfred Danegger/NHPA

Jany Sauvanet/NHPA

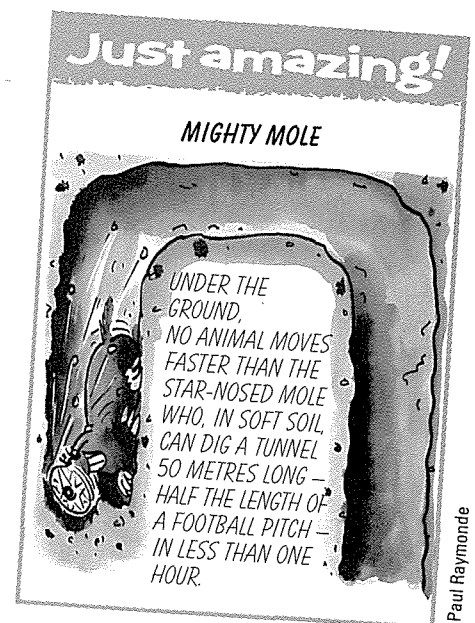
The award for true sluggishness must surely go to the Ai, or three-toed sloth, of tropical South America. On the ground, this sleepy-looking mammal takes 1 minute to cover just 2 metres. In the trees, where it is most at home, it can still only creep along at 4 metres per minute. In fact, the sloth moves so slowly that algae is able to grow in its fur, eventually staining its coat green.

ture, such as a shrew (the smallest mammal). The shrew's heart beats almost 1000 times a minute, compared to the elephant's rate of 30 beats a minute. Most animals have roughly the same total number of heartbeats over their natural life span – about 800 million.

Pace of life

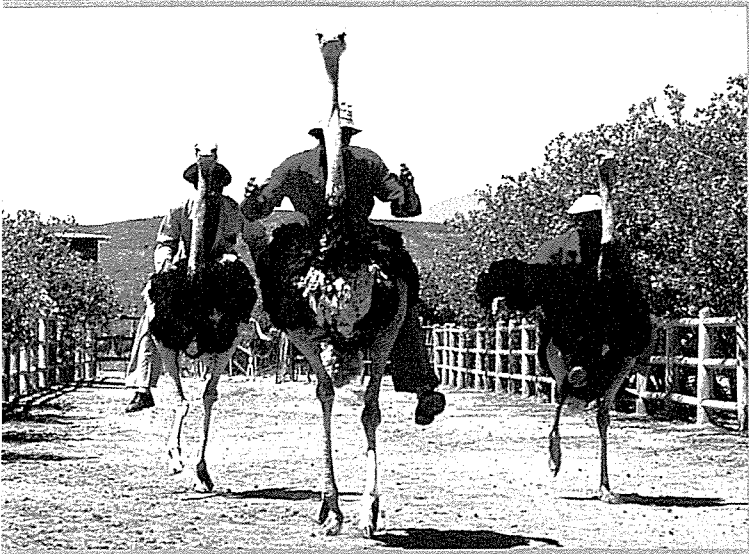
The shrew 'uses up' its quota much faster than the elephant and will rarely live longer than 17 months. In contrast, an elephant may live to be over 50 years old. (Human beings are one of the exceptions to this rule. Otherwise, a man would die at the age of 25. Animals with large brains live beyond 800 million heartbeats. A man living 70 years, and averaging 70 beats per minute has over 2,500 million beats.)

However, the shrew is not too badly off. The heartbeat rate indicates the speed of an animal's



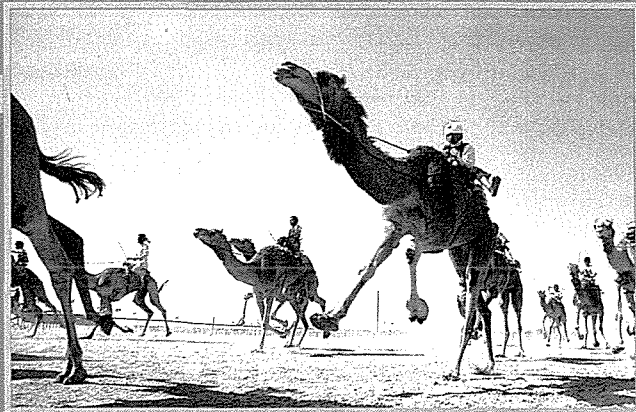
Paul Raymond





Adrian Clark/Hutchison Library

Ostriches are raced as a tourist attraction on ostrich farms in South Africa. Without a rider, the world's largest bird can run at a speed of up to 70 km per hour.



David Cannon/Alisport

As many as 50 camels in one race gallop along the 10 km track at Dubai on the Persian Gulf. Boys ride them bareback, each one attached to his camel with Velcro!

Turkey races are a regular event at Fort Pierre in South Dakota, USA, along with tenpin bowling games using frozen turkeys as the balls.



Gamma/Frank Spooner Pictures

Hippopotamuses are raced at the Florida Derby. Ostriches, lions, elephants, llamas and zebras have all been run on Derby Day.

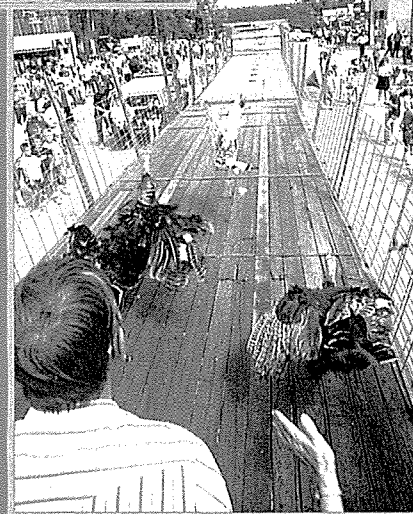


Water buffalo have been raced at Chonburi, a town 70 km east of Bangkok in Thailand, for over 200 years. The rider uses a rope threaded through the animal's nose as a rein. There are pools of water after the finishing line to slow the charging buffalo down.

Gamma/Frank Spooner Pictures



Gamma/Frank Spooner Pictures



Gamma/Frank Spooner Pictures

A trotting race at the Del Mar race track in San Diego, California. The driver is towed by the horse in a cart (called a sulky), which weighs as little as 11.3 kg.

Split Second

Greyhounds chase a mechanical hare around the track at Hackney Stadium in London (Great Britain). A greyhound can cover up to 5.5 metres in a single bound and, in a race, reach a speed of 60 km per hour.



Gray Mortimore/Alisport



High-powered motorcycles can achieve speeds in excess of 250 km/h, and accelerate from 0-100 km/h in around 3.5 seconds.

Carl Lewis, the fastest man alive, ran 100m in 9.86 seconds in 1991. Ben Johnson's 1988 time (9.79 seconds) was disqualified after a drugs test.

NEW MATERIALS, IMPROVED training methods and an ever-increasing knowledge combine, year by year, to push back the limits in the quest to be the fastest human on Earth.

At every distance, from the 60-metre dash to the 42-kilometre marathon, there has been a steady improvement in the world's best running speed over the last 50 years. For instance, the record for the mile fell from 4 minutes 6 seconds in 1937, to 3 minutes 59 seconds in 1954, to just 3 minutes 46.32 seconds in 1985.

Often the world record for a given distance improves only marginally over a period of several years, then a super-athlete comes along who far surpasses any runner before. The most spectacular example of this occurred in 1951 when the Czech, Emil Zatopek slashed 4.5 per cent off the previous best time for the 20-kilometre race.

Energy supplies

At present, there seems to be no limit in sight to further world record-breaking in track events. Athletes today train harder and more effectively than their predecessors. In

Action Plus

CHAMPION GENES TRAINING TO WIN HIGH-TECH EDGE

PACESTERS



The following table shows the changes in the women's Olympic 100 m record over the last 60 years. Although there is only 2.06 improvement it should not be

forgotten that winners and losers over this distance are separated by mere hundredths of a second, so the overall improvement is considerable.

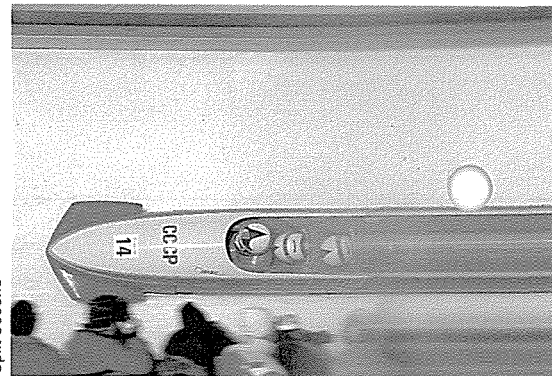
Date/Place	Name/Country	Time
1928 Amsterdam	Anni Holdmann (Germany)	13.0
1928 Amsterdam	Liz Robinson (US)	12.2
1932 Los Angeles	Stanislaw Walasiewicz (Poland)	11.9
1952 Helsinki	Majorie Jackson (Australia)	11.5
1956 Melbourne	Betty Cuthbert (Australia)	11.4
1960 Rome	Wilma Rudolph (US)	11.3
1964 Tokyo	Wyomia Tyus (US)	11.2
1968 Mexico	Wyomia Tyus (US)	11.0
1972 Munich	Renate Stecher (E Germany)	11.07*
1976 Montreal	Annagret Richter (E Germany)	11.01*
1984 Los Angeles	Evelyn Ashford (US)	10.97*
1988 Seoul	Florence Griffith Joyner (US)	10.54*
1992 Barcelona	Gail Devers (US)	10.82*

*electronic timing

this way, they adapt their bodies to cope with new extremes of speed and endurance.

During a race, oxygen breathed in by an athlete is used to fuel his muscles. If the muscles are made to burn more energy than they can get

from the incoming oxygen, they start to fall back on a small reserve of energy. This comes from turning a chemical called pyruvic acid, which is stored inside muscles, into lactic acid. But this back-up energy

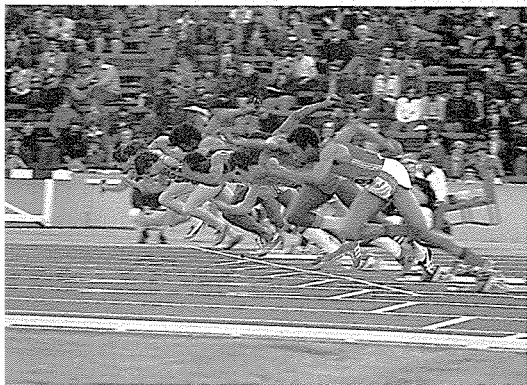


The four-man bobsleigh of the Russian national team in the 1988 Olympics at Calgary in Canada. Speeds in the bob have been recorded at over 130 km/h.

supply quickly runs out and, as lactic acid clogs his muscles, the athlete is overwhelmed by fatigue. A world-class runner is one who can perform at high speed or for long periods without suffering from lactic acid build up.

Many other factors also affect the outcome of a race or a record attempt. These include the quality of the opposition, tactics, condition

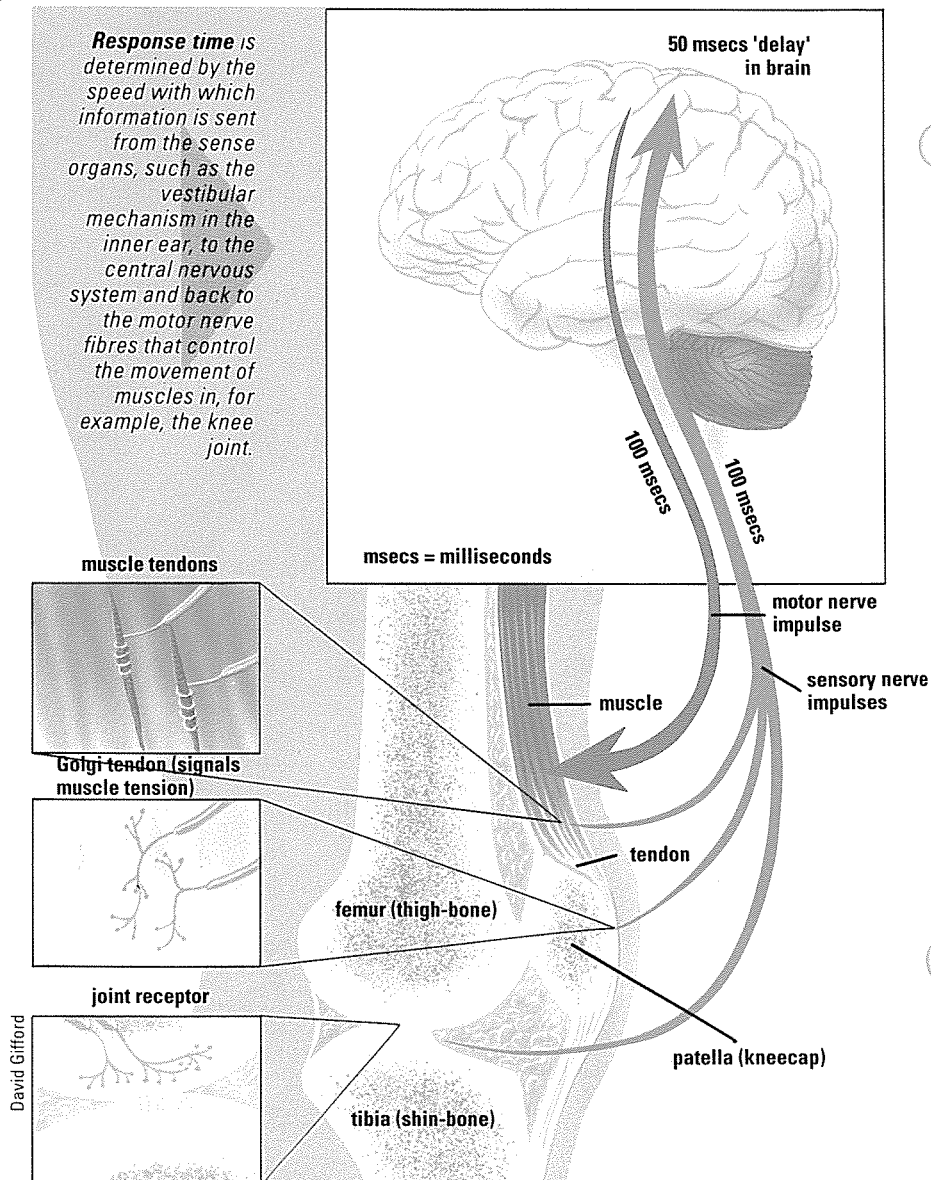
QUICK OFF THE BLOCKS



Coloursport

Fast reactions are essential in many sports, but no more so than at the start of a 100-metre race. As soon as the sprinter's ears pick up the sound of the gun, nerves from the ear pass a message to the brain. The brain then sends nerve signals to the leg muscles to start running. A top-class sprinter's reaction time from hearing the gun to leaving the starting blocks is around 200 milliseconds. In a race, the interval between the gun firing and the first athlete to leave the starting blocks is electronically timed. If it is less than 110 milliseconds, a false start is declared: the runner must have decided to go before hearing the gun.

Incredibly, Canadian sprinter, Ben Johnson has been timed off the blocks at 122 milliseconds — the tenth of a second by which he beat Carl Lewis in the world athletics championships in Rome in 1987 was made entirely off the blocks.



David Gifford





Downhill skiers encounter very little frictional resistance and can achieve remarkably high speeds. Here Oswald Tosth of Italy competes in the 1987 men's downhill World Championship. The highest average speeds for the downhill course are typically 100 km/h or more.

being driven off the tee.

Less fast, but requiring perhaps the greatest energy input of all sports, is cycling. Racing cyclists have benefited from a number of technological advances, both in the machines they ride and the clothes they wear. Two of the greatest limitations to improvements in performance are air resistance and weight. So vast resources have been poured into streamlining and weight reduction – for both the machine and the rider. Some frames are built using aluminium, alloy or carbon fibre instead of steel, but Reynolds 753 steel tube – a thin-walled but very strong tube – is still

Rex Features Ltd

of the track and state of the weather. The will to win or to beat an existing record also plays a crucial part. Half of all men who set a world track record never set another one. This suggests that the desire 'to be the best' has a real affect on performance.

Ball speeds

Ball throwing records are just as elusive. But, who can throw a ball faster – a cricket bowler or a baseball pitcher? The answer is that there is very little difference. In cricket, the quickest, electronically timed ball was delivered by Australia's Jeff Thompson against the West Indies in December 1975. It hurtled down the pitch at 160.4 km/h. This compares with the fastest baseball pitch that was accurately measured – 162.3 km/h – by Lynn Nolan Ryan of the California Angels in 1974.

Because a baseball pitch is about two metres shorter than a cricket pitch, a baseball batter has less time to react than his bat-wielding cousin before the cricket stumps. For a baseball travelling at, say 135 km/h, the flight time is only 0.45

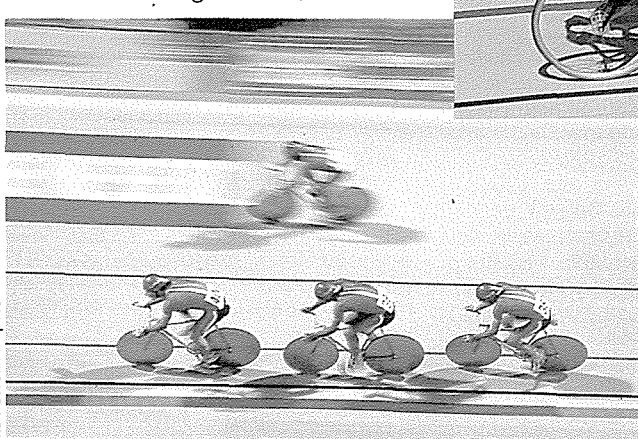
seconds. It takes a good hitter about 0.25 seconds to accelerate his bat from rest to the point where it meets the ball. This means that the batter has less than one fifth of a second to decide exactly how, or even if, to swing at the ball!

To make the batter's task still harder, whereas a cricket bat measures 10.8 centimetres across and has a flat striking surface, a baseball

Yann Guichaoua/Allsport



Track cyclists race on highly banked wooden tracks, riding special machines without brakes (above), designed to cut air resistance to a minimum. Speeds of up to 70 km/h are not uncommon.



Mike Powell/Allsport

bat is round and can be no more than 7 centimetres in diameter. This gives strong support to the claim that hitting a baseball is the most difficult action in any sport.

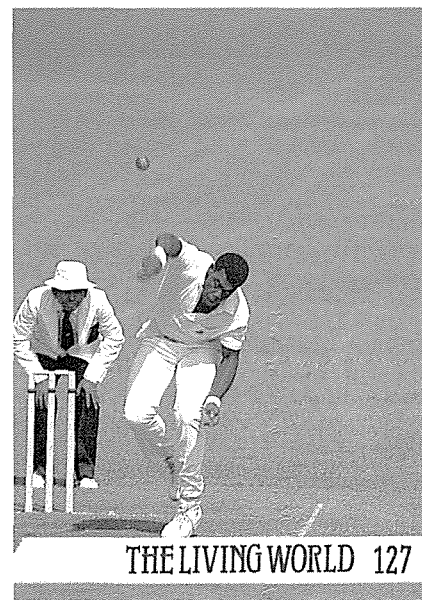
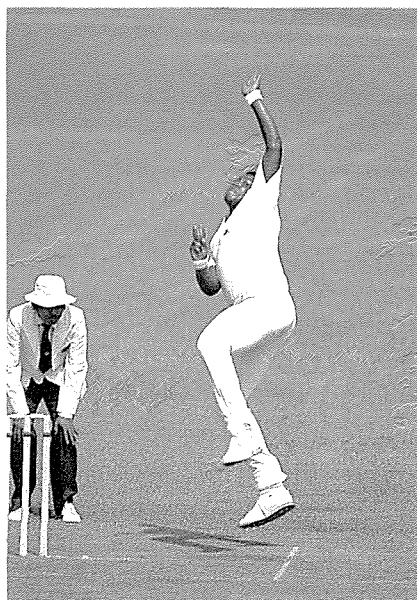
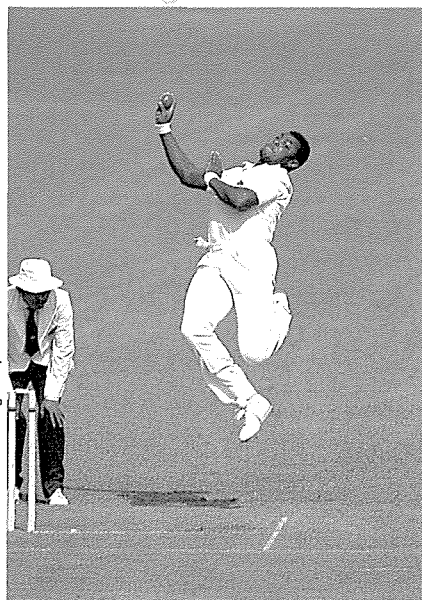
Greater speeds, however, are achieved in tennis. A serve by the American Steve Denton in 1984 was times at 222 km/h. But even this falls short of the 273 km/h electronically recorded for a golf ball

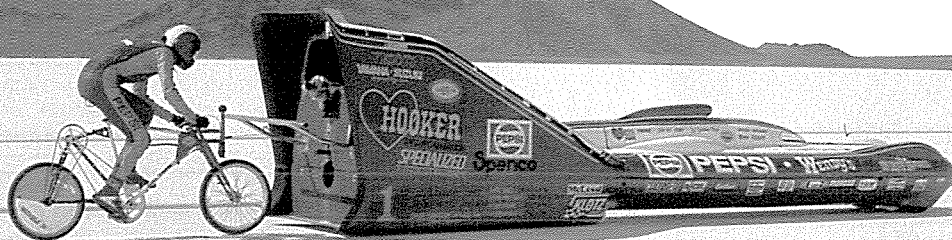
the favourite material of race-winning frame builders. The frame tubing is made more aerodynamic by being shaped, in cross-section, like a tear-drop.

Machines for track racing have 'low profile' frames, with relatively smaller front wheels. Cables are run through the handlebars and frame tubes and, in place of ordinary air, the tyres may be inflated with

A fast bowler's delivery in cricket is the result of the run-up – which may be over 10 metres – and the leverage exerted through the shoulder, arm and wrist. Here England's Dave Lawrence is shown in action before the 1992 injury which ended his career.

Michael King/Allsport





John Howard, an American cyclist, spent three years and \$100,000 building a bicycle on which he has reached a speed of 245 km/h behind a towed wall. He is now building commercial versions of the prototype for \$18,000 apiece.

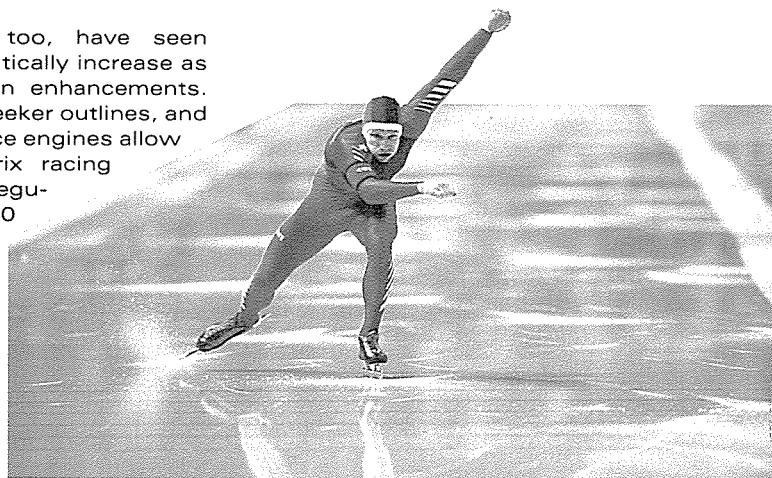
DRUGS FOLLY

The pressure to win is so great in modern sport that many competitors resort to drugs to give them a temporary – and illegal – edge in speed or endurance. Among these are amphetamines – powerful drugs which stimulate the body mentally and physically. Amphetamines work by stimulating the release of two natural chemicals, adrenaline and non-adrenaline, from glands into the blood. These chemicals cause the muscles to tense, the heart to beat faster and blood pressure to rise. They may enable an athlete to react faster or to keep going longer in order to win a race. But, in overriding the body's normal exhaustion limit, they put great stress on organs like the heart, which in some cases has proved fatal. They are among the many drugs – legal and illegal – that are banned by the International Olympic Committee.

Gamma/Frank Spooner Pictures

Motorcyclists, too, have seen their speed dramatically increase as a result of design enhancements. Lighter frames, sleeker outlines, and higher performance engines allow today's grand prix racing motorcycles to regularly exceed 250

Speed skaters, shown here at the 500 m indoor track at the Calgary Winter Olympics in 1988, have averaged speeds of up to 49.3 km/h for the oval course.

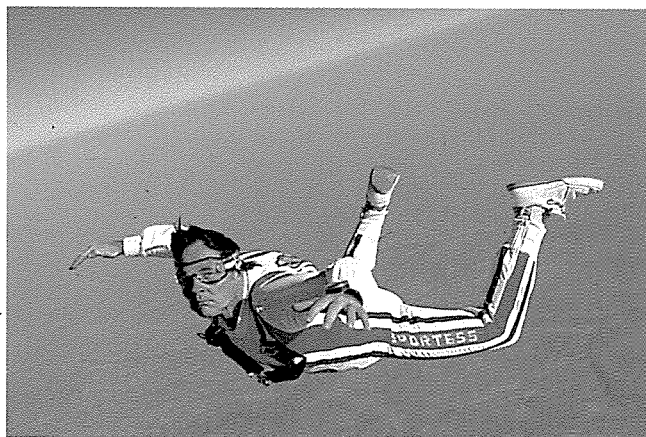


km/h. The highest speed ever attained on a motorcycle was 513 km/h by Donald Vesco of the USA in his 6.4-metre-long 'Lightning Bolt' powered by two 1016 cc Kawasaki engines.

or she can cut through the air easily. Tear-drop shaped helmets, smooth, body-contoured suits and leg fins have become familiar apparel in international competition. Major advances, too have come in the design of skis. Computer simulation, rigorous laboratory testing and field trials on specially constructed slopes mean that skis can now be made with high precision for different events. The world record for downhill skiing – set by Philippe Goitschel of France in 1993 at Las Arcs, France—stands at 233.6 km/h.

Sport

Skydivers accelerate towards earth at the rate of gravity – 9.75 metres per second². Alain Prieur, a French daredevil, specialises in jumping from a plane without a parachute, then catching it in mid-air.



Gamma/Frank Spooner Pictures

helium, which is much lighter.

Among the latest sportswear for track cyclists are pointed, streamlined shoes and helmets. These, together with skin-tight clothing, cut the aerodynamic drag on a rider as much as 10 per cent.

Breakneck biking

Attempts to break the world speed record for a bicycle are now made behind a 'pace' car with a large wind-shield fitted firmly to the rear. American John Howard reached an astonishing 245 km/h at Bonneville Salt Flats, Utah, in July 1985.

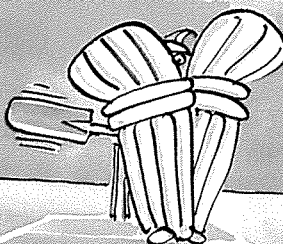
Unpowered, but by no means slow, are exponents of downhill winter sports. A hard-packed surface of ice or snow offers very little resistance, so that skiers and tobogganers can achieve very high downhill speeds. The course record on the famous 1,212-metre Cresta Run at St Moritz, Switzerland, for a one-man toboggan is 50.41 seconds – at an average speed of 86.56 km/h.

In downhill skiing, as with other racing sports, big improvements in performance have come from streamlining the athlete so that he

Just amazing!

OWZAT!

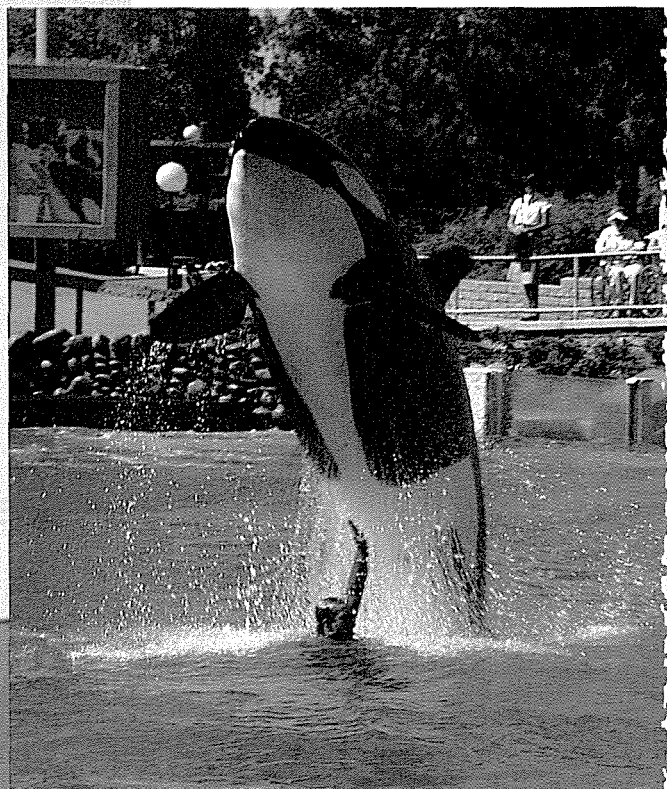
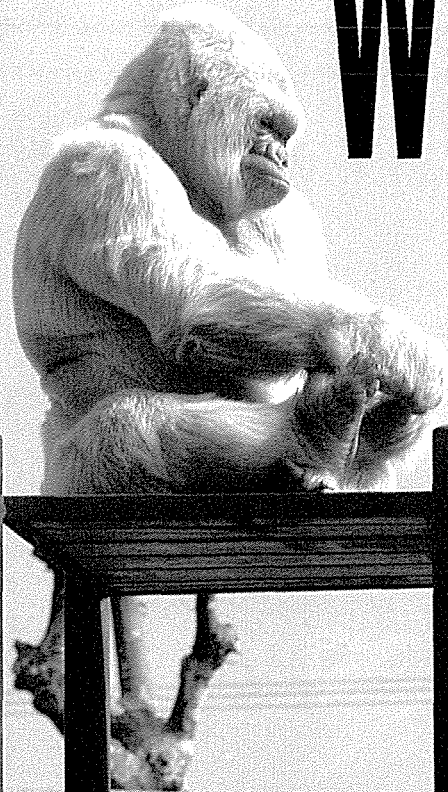
BEING HIT BY A 160 GRAM CRICKET BALL BOWLED BY A TOP-CLASS FAST BOWLER IS LIKE BEING STRUCK BY A 1 KG HAMMER.



Paul Raymond



WHERE WILD THINGS ARE



The killer whale as a performing animal. 'Shamu' has been trained to leap out of the water at Seaworld in San Diego, USA, and perform other tricks.

Sitting alone at Spain's Barcelona Zoo, far away from its native jungle, an albino gorilla stares from a platform. In the wild it would remain under cover.

Frank Lane Picture Agency

MORE THAN 350 MILLION people visit the world's 750 or so zoos each year, and in many countries, zoos regularly feature in the lists of top ten tourist attractions. But are zoos just tourist attractions, or do they serve any scientific purpose?

Modern zoos perform three main roles. First and foremost, they allow scientists to study animals and to find out how they 'work' and live. With this knowledge, organizations can set up proper wildlife conservation and preservation schemes. Biologists can also make comparative studies of animal and human anatomy (structure) and physiology (functioning) to shed light on how the human body works and it can

best be treated medically.

Second, zoos allow species that are threatened with extinction to be increased in number and to be bred in captivity. Hundreds of endangered species have been helped

in this way, including the white rhino, mountain gorilla, giant panda and the Californian condor.

Animals such as the Arabian oryx and Père David's deer have been successfully bred in captivity and

PROFILE

THE COSTS OF CARE

Animal	Cost per year (£)*		
Ant	15	Chimpanzee	750
Toad	30	Gorilla	1,000
Cobra	80	Giraffe	1,800
Squirrel monkey	150	Lion	2,300
Alligator	300	Californian sea lion	3,000
Penguin	350	Koala bear	4,000
Grey wolf	600	Asian elephant	7,000



over thousands of square kilometres in the wild, and have problems adapting to the confines of a zoo. Even in Washington's Tacoma Zoo, which has one of the most advanced enclosures, the



Rex Features



Zoo keepers have to care alike for little and large animals. The baby parrots (left) are being hand-reared, which involves feeding them with a syringe. The elephant (above) likes nothing more on a hot day than being hosed down by its keeper.

they will be enclosed by a wall of one-way glass through which people can be neither seen nor heard.

Most city zoos have now combined resources with rural nature parks in which the animals can spend some of their time in large open spaces. For example, London Zoo is linked to Whipsnade Park, an area of about 200 hectares. In such areas it is often possible to drive through the enclosures and to watch the animals behaving as if they were in the wild.

Rex Features

PERFORMING ANIMALS

In most countries there are now strict rules about how circus and other performing animals should be looked after, trained and worked, covering areas such as:

- larger cages and exercise pens
- a greater emphasis on training by reward, rather than punishment
- regular inspection by vets

Most performing animals are bred in captivity and know no other life, having never lived in the wild. But animal rights campaigners still claim it is cruel to make animals perform and to keep them in such unnatural conditions.

Phillip Coffey/Jersey Wildlife Preservation Trust

Lion tamer – a vet examines Floyd, a 7-year-old lion, under anaesthetic at a zoo in England.

Floyd had been bitten on the leg by another lion.

Fragments of broken bone were discovered in Floyd's knee, so he was given antibiotics to protect against infection. An operation then removed the bone fragments.



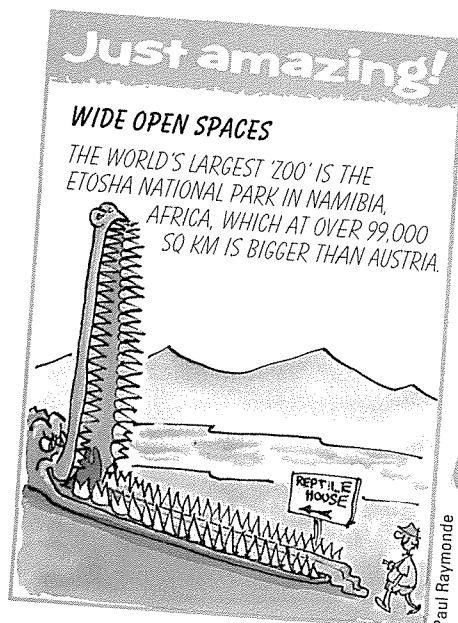
polar bears and elephants show signs of stress.

Britain's Bristol Zoo is showing a way forward by hiring a behavioural psychologist to find ways to keep its polar bears happy. They are now given toys to play with and encouraged to forage for their food. The bears' symptoms of stereotyped behaviour have since disappeared.

Home from home

But for many other animals, zoo managers and zoo architects have succeeded in improving their quality of life in captivity by building enclosures that re-create some of their natural environment. The new gorilla house at London Zoo plays recorded bird songs and the sounds of other gorillas. It also has a sprinkler system to simulate the rainfall of the gorillas' natural habitat. Because gorillas are naturally shy and so very wary of humans,

Robert Harding Picture Library



Paul Raymond



Cross-section of a plant stem reveals air-filled pith cells surrounding the plant's food and water carrying tubes (the compact bundle in the centre).

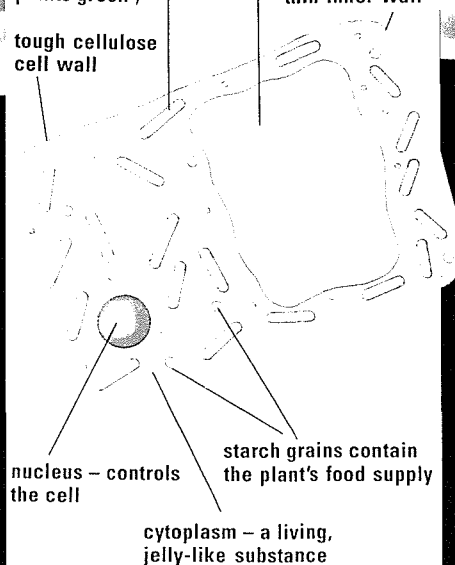
BIOLOGICAL FACTORIES

Plant Cell

chloroplasts contain chlorophyll (the substance that makes plants green)

vacuole – a space filled with cell sap
cell membrane – thin inner wall

tough cellulose cell wall



EVERY LIVING ORGANISM IS made up of cells. Some cells live alone as microscopic creatures; others form larger organisms as diverse as a tiny flower and a whale.

An animal is made up of many different types of cell. Of the 75 million million cells in the human body, most are specialized to carry out one particular job. For example:

- nerve cells are long and thin – nerve impulses travel along them
- skin cells are flat – they protect the body
- blood cells are disc-shaped – they carry oxygen around the body

Specialized cells, when grouped together in the human body and other organisms, are called tissues.



Chemicals of life

In spite of their different tasks all cells work in the same basic way – along the lines of a factory. A continuous flow of raw materials enters the cell. These are converted into chemicals, such as hormones or enzymes, which are essential to the basic functioning of the body. They are then transported to other cells or used within the same cell.

No cell lives for ever. Some cells such as white blood cells, live for a

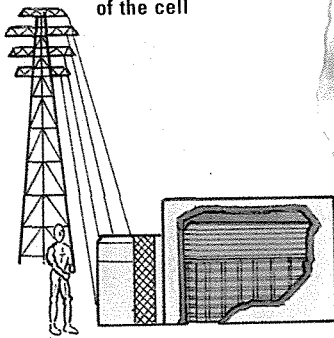


Animal Cell

the cell membrane is the 'factory wall' – it controls substances that enter and exit the cell

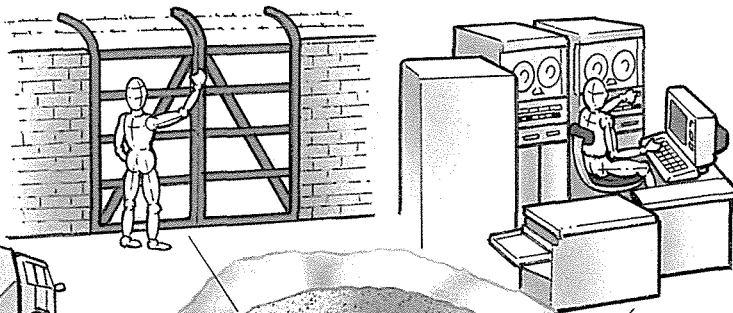


▲ lysosomes are 'refuse collectors' that break down waste products and send them out of the cell

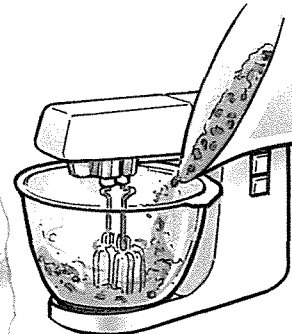
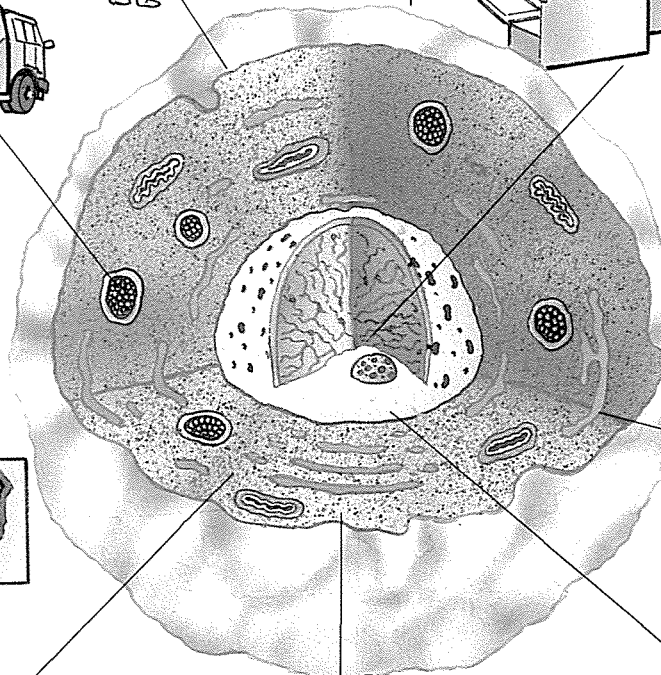


the mitochondria are 'power generators' – they convert food into energy

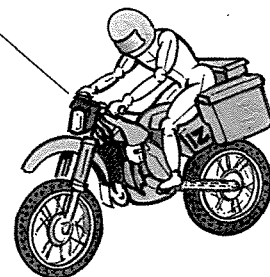
the cytoplasm is the environment in which all parts of the cell are suspended



the nucleus is the 'control room' – it determines and controls all the cell's activities and sends instructions to other parts of the cell

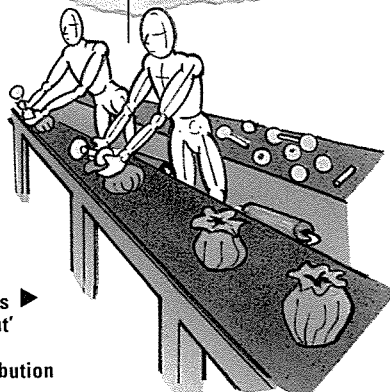


▲ the endoplasmic reticulum is the 'production plant' – it contains ribosomes: 'machines' that produce the chemicals the body requires

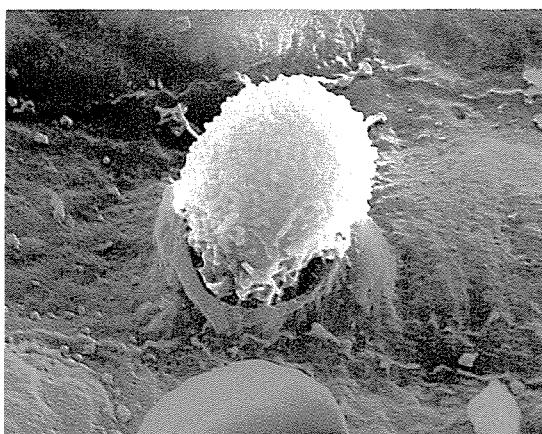


RNA are the 'messengers' that carry instructions from the nucleus to other parts of the cell and take information back to the nucleus

the golgi complex is the 'packaging plant' where proteins are packaged for distribution



John Houghton

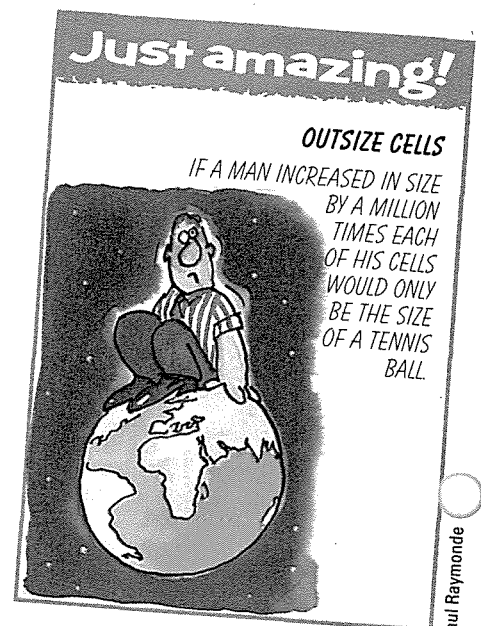


few days. Others, nerve cells for instance, can live for over 100 years. In some cases, dead cells are replaced by new ones in a process known as cell division. Some cells, such as human brain cells, are never replaced.

Animal or vegetable?

Plant cells are bigger than animal cells and are usually rectangular in shape. They are enclosed in a layer of cellulose and often contain starch grains and chlorophyll. Animal cells have no cellulose wrapper and never contain chlorophyll or starch grains.

Blood consists of a liquid called plasma, in which float red blood cells (1), white blood cells (2) and platelets (3). Platelets help blood to clot in wounds. A white blood cell exits through the wall of a blood vessel (top left).



Paul Raymond



ANIMAL

- WAR ON WILDLIFE
- RARE SPECIES
- ZOOS TO THE RESCUE

Armed wardens patrol the African bush in search of poachers. Bands of ivory hunters have been known to massacre entire elephant herds.

Anthony Bannister/NHPA

Gamma/Frank Spooner Pictures



WATCH

POACHING HAS BECOME A multi-million-pound industry. Many animal and plant species on the verge of extinction are illegally slaughtered every year.

But at last, as countries begin to take action against the ruthless killers, the hunters have become the hunted. In some of the biggest game reserves in Africa, rangers armed with semi-automatic rifles are ordered to shoot on sight anyone caught killing protected wildlife.

Elephants are among the most threatened creatures because of their ivory tusks. Ivory, which is made of a similar substance as

teeth, is exported, carved into trinkets and sold at very high prices to tourists in countries such as Hong Kong and Japan.

The poachers, who are increasingly well armed and organized, can earn what to them would be a year's income from selling one set of tusks, for around \$220 per kg.

Deadly demand

To satisfy the demand, many more elephants must be killed nowadays than in the past. This is because the majority of large bull elephants — whose tusks can reach several metres in length and weigh up to 80 kg — have been shot.

PLANT POACHING

Like animals, plants are also poached for their beauty and value. In June 1989, a Briton, Henry Azadehdel, was sentenced to one year in prison for smuggling hundreds of rare, wild orchids into the country. Collectors around the world will pay high prices for these beautiful flowers, plundered from tropical jungles. A British orchid, the lady's slipper, has also suffered. It once grew in the North of England, until Victorian gardeners and orchid fanciers started collecting it in large numbers. Today, a single, closely guarded plant is all that survives in the wild.



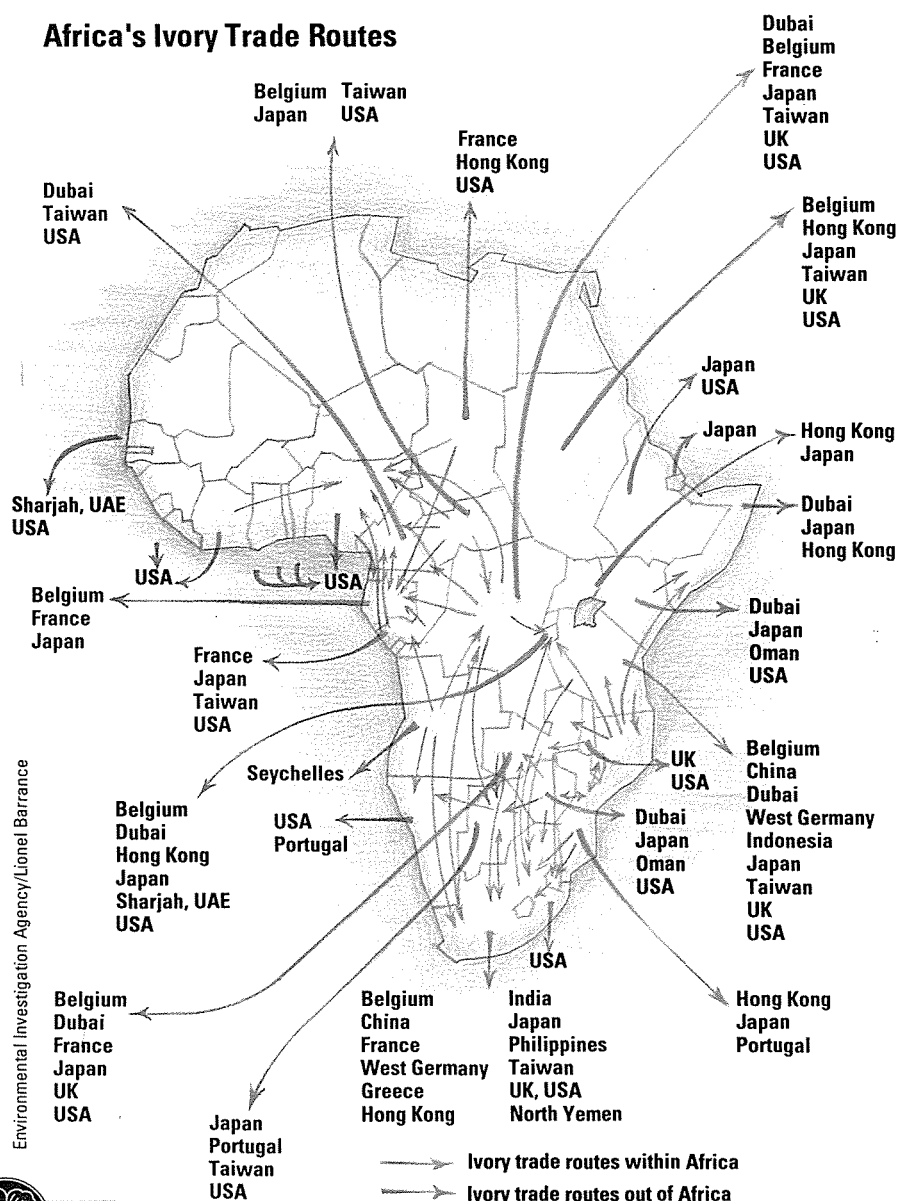
Jonathan Scott/Planet Earth Pictures

Many nations are members of CITES (the Convention on International Trade in Endangered Species of Wild Flora and Fauna). This supports a worldwide ban on the export of ivory. But not all countries agree that stopping the ivory trade is the best way to protect the elephant.

Legal killing

Game wardens in South Africa and Zimbabwe, for instance, legally kill a certain number of elephants each year. The meat goes to local people; skin and ivory to the international trade. Money from these exports is ploughed back into conservation.

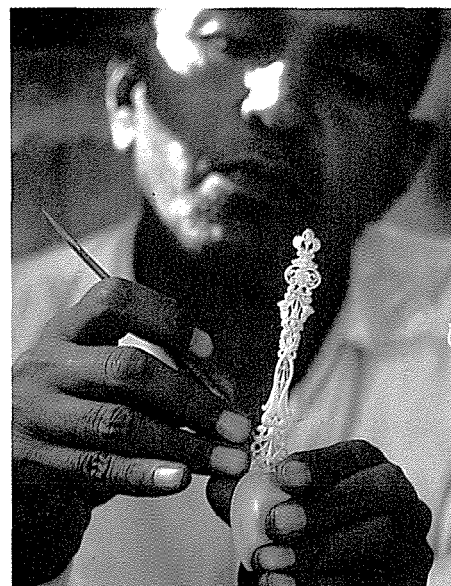
Africa's Ivory Trade Routes



These nations claim that, as a result, their elephant populations are rising.

Countries in East Africa, however, such as Kenya and Tanzania, are vigorously opposed to the sale of ivory. These two countries have been worst affected by poaching. Since 1973, Kenya has lost 72 per cent of its elephants within protected areas, and 92 per cent of those outside. Now, however, it has stepped up its war against the poachers by employing more game wardens armed with military hardware. Over the next few years it should become clear which method — legal culling or total protection — has achieved the best results for the elephant.

Most tusks are shipped out of Africa to be worked into jewellery, dagger handles, piano keys and other artefacts.



Many species are now on the very brink of extinction because of poaching and the destruction of their natural habitats by Man. The world's rhinoceros population has been devastated. Tragically, the only reason this animal is killed is so that its horn can be carved into ornamental dagger handles or powdered to make an aphrodisiac, or love potion. Rhino horns are made of matted hair – a substance which has been scientifically proved to have no aphrodisiac quality at all.

 Slaughter

A solitary beast, the African rhino has had its numbers slashed from 65,000 in the late 1960s to less than 3,500 today. At the present rate of decline, it will be extinct in the wild by the end of this century.

Most of Africa's ivory goes to Japan and Hong Kong. The amount fell from 900 tonnes in 1985 to 300 tonnes in 1988, but elephants still face extinction.

THE VANISHING WHALE

The biggest animal that has ever lived, the blue whale, may soon be just a memory. Only 22 blue whales were sighted in southern oceans between 1983 and 1989, suggesting that their worldwide population may be less than 2,000. This compares with an estimated 250,000 before hunting began in 1890. Other species of great whale, such as the fin, sperm and humpback, have fared little better. It may be that their numbers are now so low that they will never recover. Even so, some countries including Japan, Iceland and Norway, continue to hunt whales.

1987, a similar survey found none. Poaching and destruction of the forests in which they lived have wiped out this species in the wild.

A similar fate threatens the great apes — chimpanzees and gorillas in Africa, and orang-utans in Asia. Most endangered of all is the mountain gorilla, of which only about 500 are left in two tiny areas of central Africa.

In the future it may be that zoos represent the last hope for species facing extinction. Already there have been a number of attempts to reintroduce endangered animals into the wild that have been bred in

Just amazing!

MAMMOTH TASK

WEST GERMAN IVORY CARVERS, FACED WITH A BAN ON IMPORTED ELEPHANT TUSKS, HAVE COME UP WITH AN UNUSUAL ALTERNATIVE. THEY PLAN TO USE IVORY FROM 20,000-YEAR-OLD MAMMOTHS FOUND FROZEN IN SIBERIA!



Paul Raymond

captivity. But this is much easier with some species than others.

The reintroduction of the Arabian oryx, for instance, has been a great success. Hunters exterminated the last wild herds of this animal in 1972, but biologists in America managed to preserve and build up a herd in captivity. By 1984, they were able to release 21 oryx in two separate groups in the desert of central Oman. Their numbers are now increasing.



Francois Gohier/Ardea London

As a last desperate measure, game wardens in north-west Namibia have begun darting the remaining desert black rhinos with tranquillizers and then sawing off their horns to dissuade poachers. Unfortunately, without their horns rhinos are unable to defend themselves.

Wiped out

In other cases of threatened wildlife, help may already be too late. A 1970s survey of Manchurian tigers in their last remaining stronghold in north-east China revealed only seven individuals. In

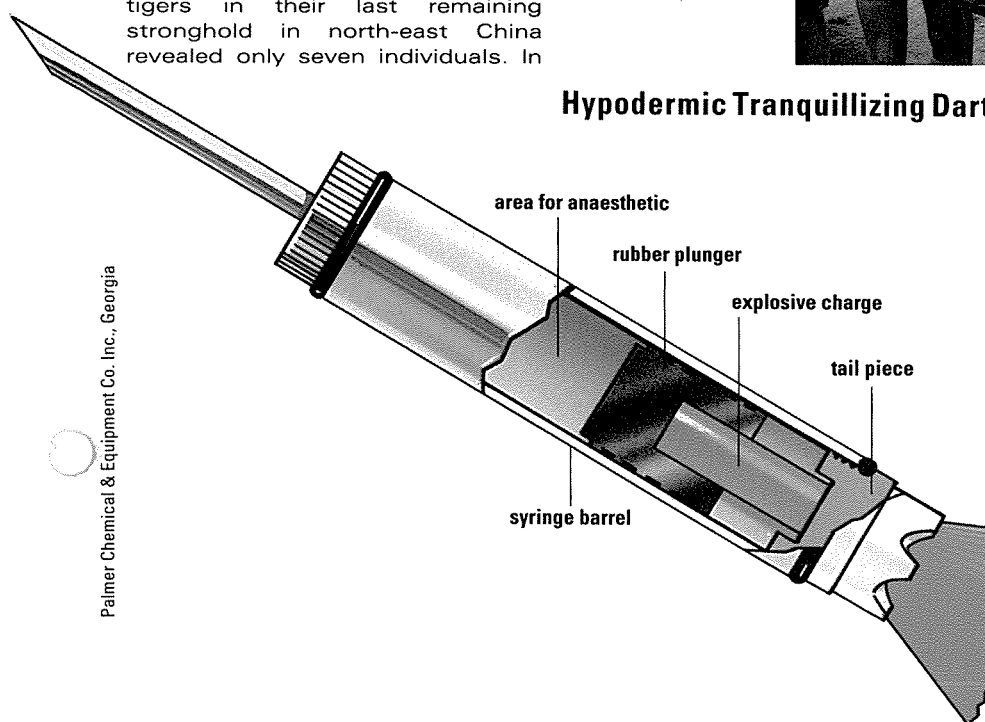
A wound is treated by game reserve wardens, who are in the front line in the fight against poaching.

High-powered darts fired from special guns are used by wardens to capture large animals that need veterinary care.



Rafi Ben Shahr/Oxford Scientific Films

Hypodermic Tranquillizing Dart



Palmer Chemical & Equipment Co. Inc., Georgia

Attempts to reintroduce orang utans into the wild, however, have proved far more difficult. One reason is that the orang's environment is complex — it has a lot to learn just simply to stay alive. Newly released orangs, for example, tend to move about on the forest floor where they are easy targets for predators. They also range over a fairly small area, which makes it hard for them to find enough to eat.

Survival

Native orangs, by contrast, spend much of their time in the trees and have no fear of wandering throughout a territory of 2–3 sq. km. If captive animals can spend time with wild ones before release, their chances of survival greatly increase.

Joe Lawrence





David Campbell/OSF

The Black Hanur lives in the humid forests of Borneo. Its range is being squeezed by the spread of agriculture, logging, and fires.

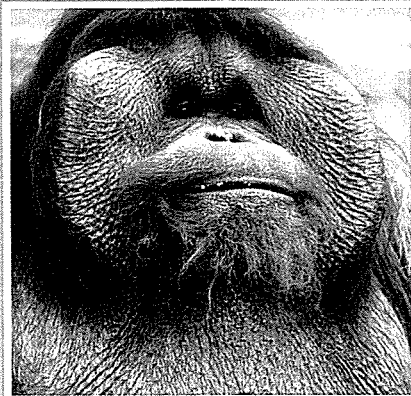
Salmon-crested cockatoos, found on the Indonesian island of Sumbawa, are facing extinction because they are prized as cage birds.



Adam Compas/Bruce Coleman Ltd.

The Philippine eagle is threatened by deforestation. Its slow flight also makes it an easy target for hunters.

Bruce Coleman Ltd.



Adam Compas/Bruce Coleman Ltd.

The orang-utan population has been severely reduced by deforestation. Less than 2,000 survive in the wild.

The common rabbit bandicoot is found in the arid areas of Western Australia. Once hunted for its pelt, it is now close to extinction.

Mountain gorillas were discovered by Europeans in the 1890s. In this country, hunting has reduced their population to less than 400.

Lee Bae/Bruce Coleman Ltd.



Nat King/WWF



Lee Bae/Bruce Coleman Ltd.



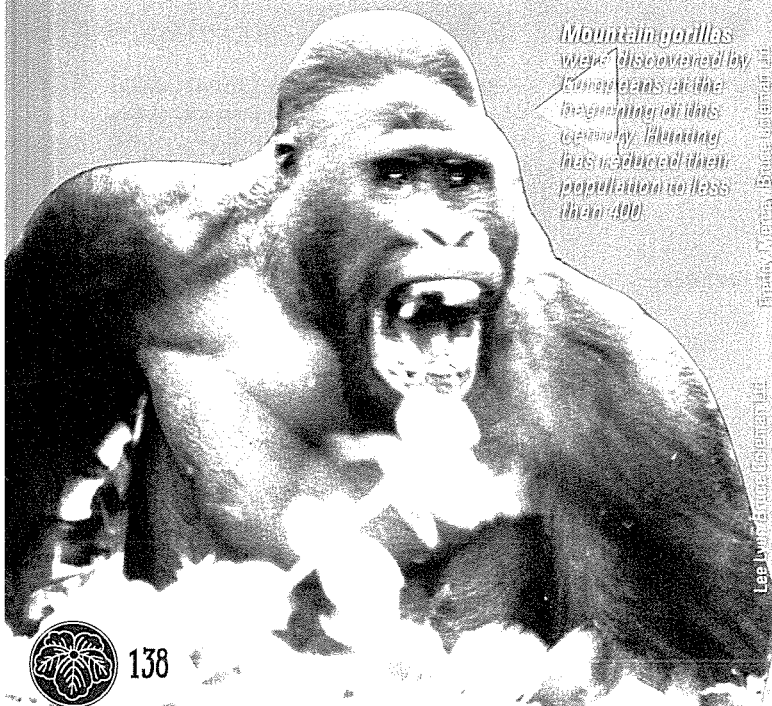
Alan & Sandy Lang

Leopards have been hunted for centuries for their much-valued fur. The Chinese leopard is now a protected species.

Giant pandas, first discovered in the 1890s, live in the mountain forests of China. Less than 1,000 survive in the wild.



Alan & Sandy Lang



■ CAPTURING PREY

■ ELECTRIC SHOCKS

■ ARTICULATED JAWS

EARTHLY MONSTERS

CREATURES THAT LOOK monstrous have always exerted a fascination and have been the inspiration for many horror films, and books. Yet many of these animals are not as fearsome as fiction and folklore would have us believe.

Few creatures are as feared – and as fearsome – as sharks and their close relatives, mantas and rays. The most awesome of these fish, the great white shark, inspired author Peter Benchley to write the book and film *Jaws*. Equipped with a huge, crescent-shaped mouth, armed with an array of jagged teeth, the great white is a killing machine. This

shark can grow to a massive length of over 30 metres and weigh up to half a tonne.

● Maneater

The great white shark also popularly known as the maneater, feeds mainly on seals and porpoises, but will eat just about anything to satisfy its enormous appetite.

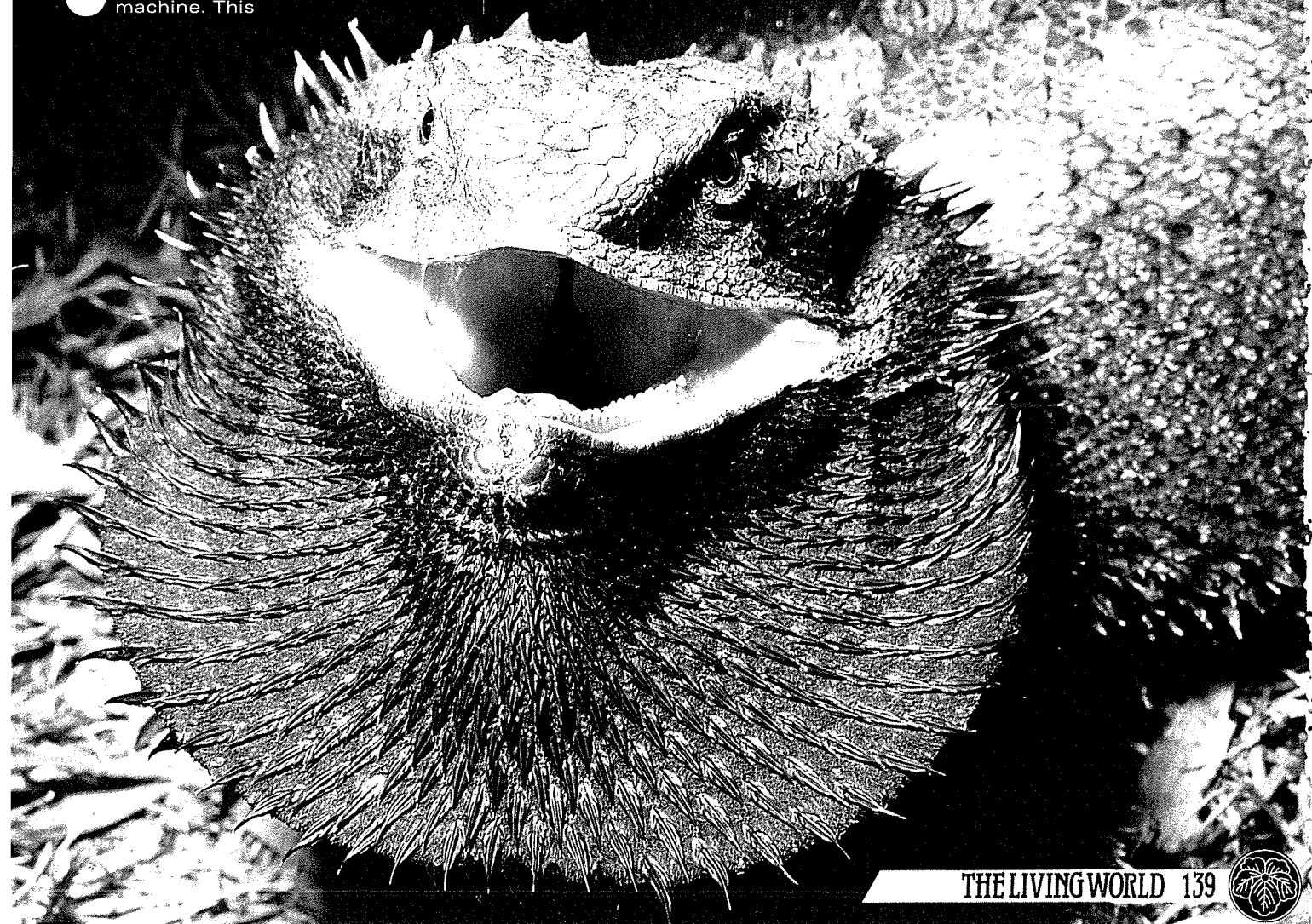
There are about 100 shark attacks on people each year, most of

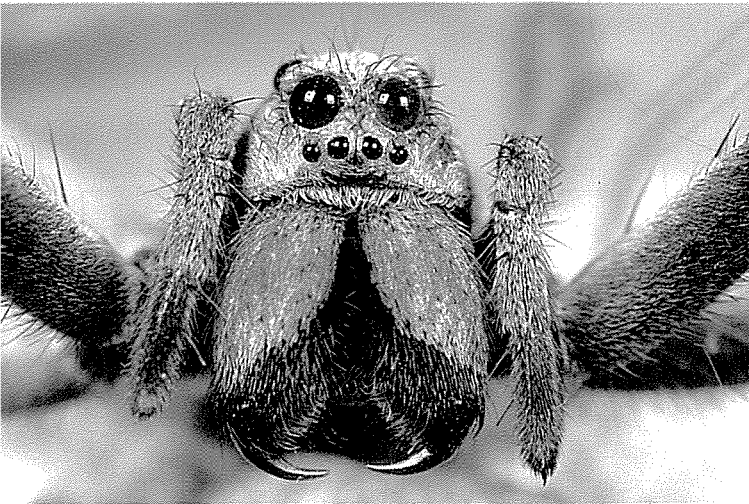
which take place in shallow, warm water. The shark usually surprises its victim with one huge bite, then often retreats briefly before returning for the kill. Great whites have been known to jump out of the water to attack fishermen. Sharks have even been known to attack each other in a frenzy of feeding.

The 'devilfish' mentioned in ancient mariners' tales is the Pacific manta ray. This can grow to 6

Bearded dragons ward off enemies by expanding their mouth to emphasize their pointed scales. Other lizards have similar deterrent displays.

Fritz Prenzel/Bruce Coleman Ltd





Spotting prey is no problem for the wolf spider – it uses one or all of its eight eyes! Some wolf spiders measure up to 250 mm across. Male wolf spiders use their legs to signal to prospective mates.

they are more likely to attack their real-life enemy, the sperm whale, than a submarine or a person. Squids' bodies can measure up to 6 metres long, from which project eight arms, and two longer tentacles 11–13 metres long. Giant squid live in deep waters, feeding on fish and smaller squid. They seize their victims with their arms and tentacles, paralyse them with poison, then bite off and swallow small pieces of flesh. In encounters with sperm whales, squid often inflict deep wounds.

Octopuses, like squid, have sucker-bearing arms that they

Anthony Bannister/NHPA

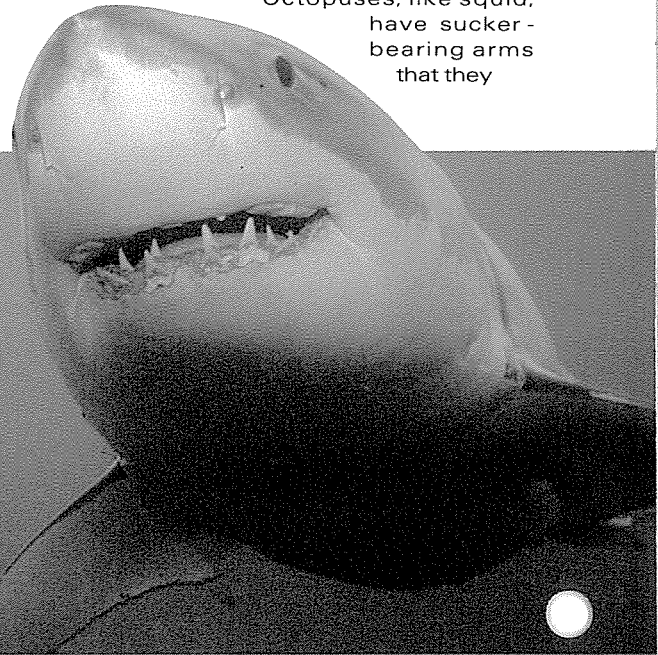
across and weigh 1,600 kg. It gets its name from the two horn-like fins that project forwards from its head. With its wide, wing-like pectoral fins and its long, whip-like tail that has sharp spines at its base, the manta is an awesome creature. However, it feeds on plankton and small fish, sifting them from the water as it swims along. Some much smaller rays, such as the torpedo ray, can administer electric shocks to stun prey and to defend themselves.



Deep-sea monsters

Jules Verne, in his novel *20,000 Leagues Under the Sea*, described how the submarine *Nautilus* was attacked by a giant squid. Such deep-sea monsters do exist, although

The great white shark has a bite 300 times stronger than a human's. An animal 2.5 metres long can exert a pressure of almost 3 tonnes per sq/cm. Great white sharks can reach over 10 metres in length.



THE PRAYING MANTIS – A HIDDEN HUNTER

Like many insects, the praying mantis is shaped and coloured to blend in with its background. Many are brown or green to match the foliage where they sit motionless, waiting for prey. The mantis stands on its middle and hind legs with

the forelegs raised, as if in prayer. Its front pair of limbs are jointed rather like a penknife, with a sharp serrated edge designed to seize and hold the unfortunate victim. Mantids are slow-moving, which is why they tend not to pursue

use to capture prey. However octopuses are smaller animals – their tentacles rarely exceed 10 metres. They emerge from rock crevices to attack their prey. Like squids they squirt ink into the water to deter predators. They have been known to seize swimmers, but more out of curiosity than aggression. Unlike squids, octopuses can subdue their prey with a poisonous bite.



Monster snakes

Some snakes, particularly non-poisonous pythons and anacondas, grow to monstrous proportions. The Indian python can reach 6.5 metres in length. The longest recorded python, shot in the Malay Archipelago, measured 10 metres. Non-poisonous snakes kill their prey by suffocation, winding coils of their body around the victim and literally squeezing the life out of it.

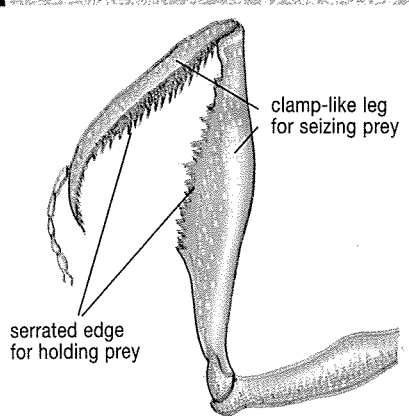


Poison

The largest venomous snake in the world is the king cobra. Fully-grown animals average 3.9 metres. Venomous snakes, such as adders, vipers and rattlesnakes, kill their prey by injecting them with poison from long fangs. When the snake is on the attack, the fangs are extended and point forward. Snakes usually have to inflict one stab to inject a dose of

Marty Snyderman/Planet Earth Pictures

John Houghton



Foreleg of the Mantis

their prey but wait till it strays within reach. They live on flies, grasshoppers and caterpillars, and the voracious female eats the male during or after mating. The larger South American species attack small frogs, lizards and birds.

David Overcash/Bruce Coleman Ltd





Weintraub Film Library/BFI



Komodo dragons are the largest lizards in the world. A true relic of prehistory, the Komodo will devour goats and deer. Man-made monsters (left) are often modelled on real-life reptiles.

swarms and readily sting people who threaten them. In one case, a young Zimbabwean was stung 2,243 times by a swarm of wild bees. Incredibly, he made a complete recovery.

Killer bees

The most dangerous species is the so-called 'killer bee', which was the result of genetic experiments with African bees. In the 1950s, 26 colonies of killer bees escaped from a research centre in Brazil. They have since spread throughout South America and now outnumber normal honeybees. Although their sting is no more lethal, killer bees will attack in much greater numbers and continue

Philippa Scott/NHPA

J. Mackinnon/Planet Earth Pictures

poison. When the snake closes its mouth, the fangs fold back into a recess in the roof of the mouth. The larger snakes will prey on each other. The black-headed python specializes in killing other snakes – even the most venomous species.

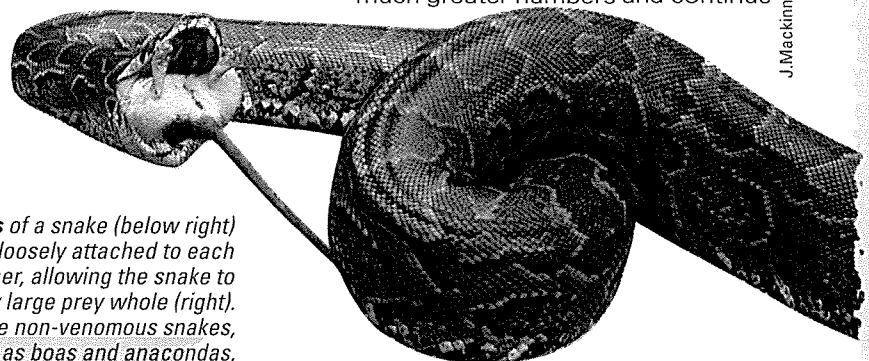
Snakebite

About 30,000 people die from snakebites each year. Despite this, most snakes are not aggressive towards animals and will not attack unless threatened. Many of their threatening gestures, such as hissing and rattling tails, are intended to ward off predators.

Looking like a spider and measuring up to 8 metres between the tips of its outstretched legs, the Japanese spider crab is feared by fishermen who occasionally catch one in their nets. It commands great respect as it

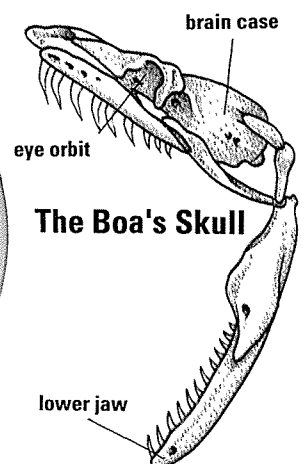
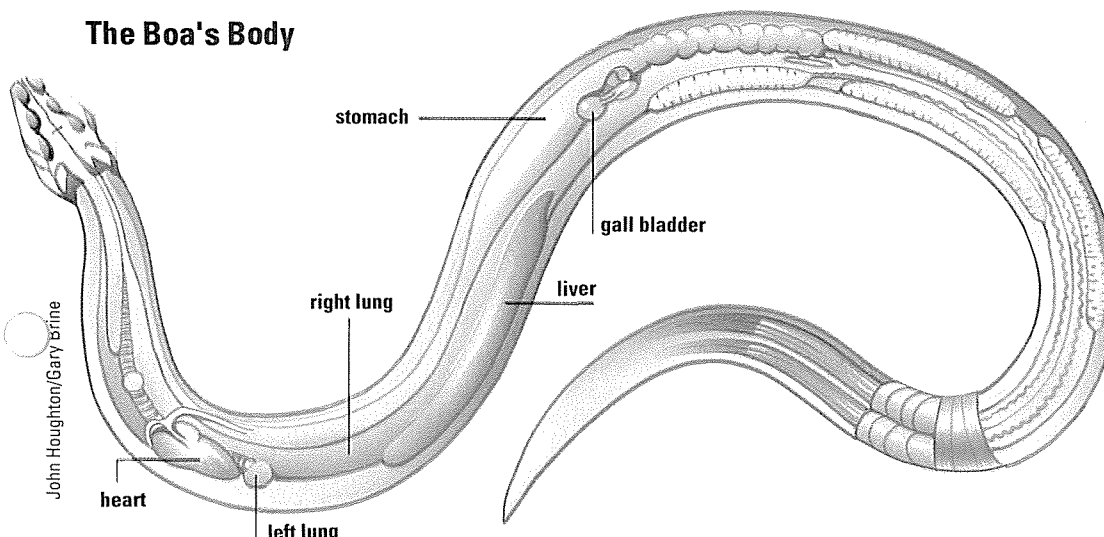
can give a nasty nip with its pincers.

The Birds and *Return of the Vampire* are just two films in which winged creatures are depicted as monsters – and with good reason to some extent. Many types of bee fly in



The jaws of a snake (below right) are only loosely attached to each other, allowing the snake to swallow large prey whole (right). Large non-venomous snakes, such as boas and anacondas, prey on animals as big as antelopes and deer.

The Boa's Body



The Boa's Skull

John Houghton/Gary Brine



for up to half an hour. Normal honey bees will defend a few metres surrounding a colony, and attack only when severely provoked.

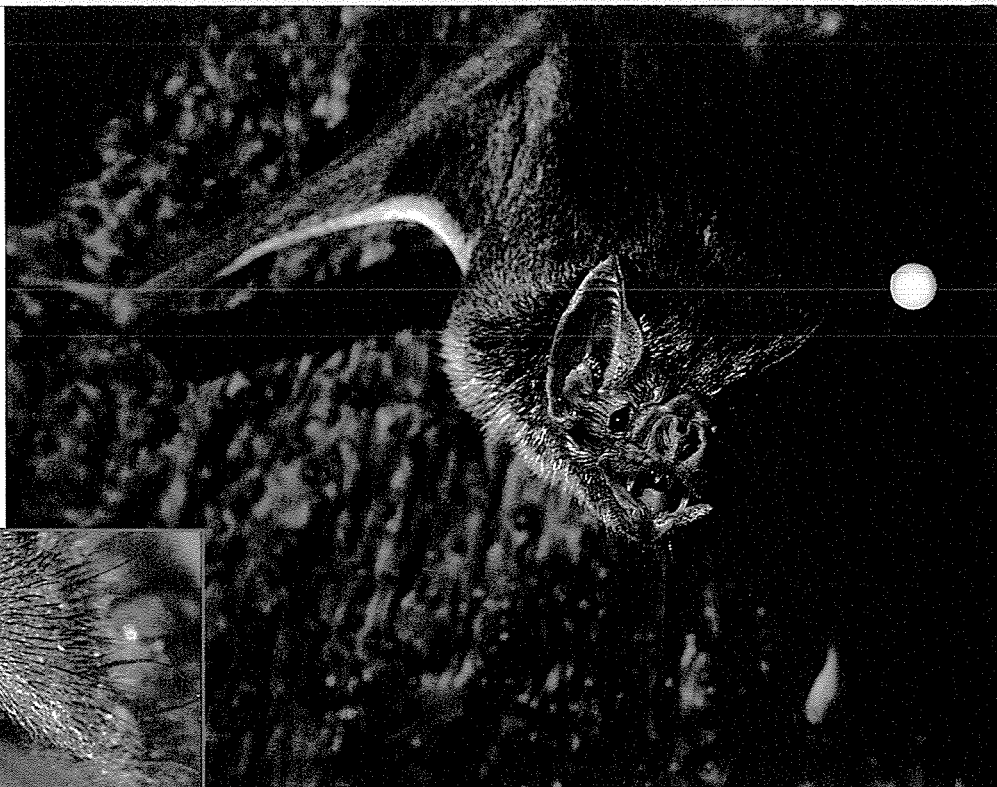


Attack

Killer bees will defend a 200-300 metre area and are much more likely to attack if threatened. An estimated 40 people have died since the bees first escaped.

Blood-sucking vampire bats also conjure up truly gruesome images. Yet contrary to common folklore, these winged mammals, which are only about 7 to 10 cm long, feed on

Gunter Ziesler/Bruce Coleman Ltd



The vampire bat makes an incision in its sleeping prey's skin with two razor-sharp teeth (left), then laps up the blood. These bats each drink about 26 litres of blood a year.

strikes out at any insect or animal that comes near. Its bite is highly toxic and nearly always fatal.



Horror

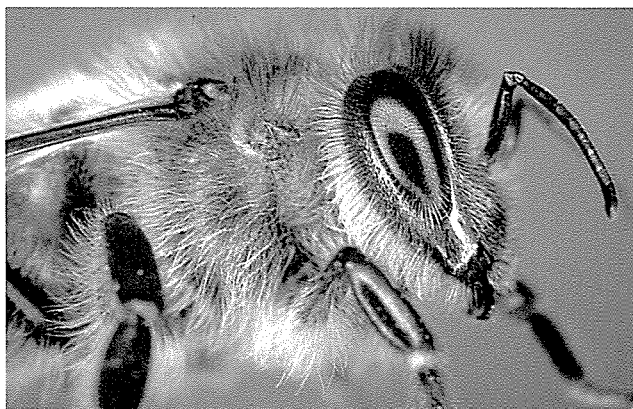
When not using spiders, film producers often use snakes, lizards and other reptiles to create fear and horror. Think of some of the scenes in *Raiders of the Lost Ark* and *Romancing the Stone*. In *The Lost World* live reptiles were cleverly disguised as dinosaurs in an attempt to make the film's various monsters move more naturalistically.

Species such as the Komodo dragon are indeed monster lizards. Komodos lived unknown to Western man on a group of small Indonesian islands until 1912, when a pioneer airman made a crash landing on one of the islands. He was horrified to discover large numbers of these real-life carnivorous dragons.

Stephen Dalton/NHPA

Dr J. Burgess/Science Photo Library

Even honey bees look like alien creatures when viewed close up. This worker honey bee, unlike the queen bee or drone, has a spoon-shaped jaw, minus serrations, so that it can mould wax.



FIGHTING PHOBIAS

Many people have an understandable fear of creatures such as snakes and spiders. But when that fear becomes so intense and irrational as to change a person's behaviour, it is called a phobia. This sometimes stems from bad experiences in a person's past or even a single incident in early childhood: the sufferer can no longer remember. Psychotherapists may treat the disorder with hypnosis, by helping the patient recall the experience in their subconscious. In some cases, the phobic person is gradually faced with the animal that they fear. For instance, an arachnophobe – someone with an irrational fear of spiders – will be shown photographs of spiders and eventually gently encouraged to handle one.

the blood of horses, cattle and birds, and only occasionally on the blood of humans. The bats attack their victims while they are asleep, sucking the blood from a bite they make on the neck or leg. The real danger of vampire bats, though, is the deadly diseases such as rabies that they transmit while feeding.



Venomous spiders

Tarantula is the name commonly ascribed to any large, hairy, poisonous spider. All spiders use venom to paralyse their prey, though only a few are powerful enough to pierce human skin. One that can is the funnel-web spider of Australia, one of the most poisonous spiders in the world. This species – so called because it makes its lair by spinning a tube of silk in a hole or crevice –

Just amazing!

SLOW CENTURY

THE SLOWEST GROWING SPECIES IN THE ANIMAL KINGDOM IS THE DEEP SEA CLAM – *TANDARIA CALLISTIFORMIS* WHICH TAKES 100 YEARS TO REACH A LENGTH OF 8MM.



Paul Raymond



■ BALEEN WHALES

■ ECHO-LOCATION

■ FACTORY SHIPS

OCEAN GIANTS

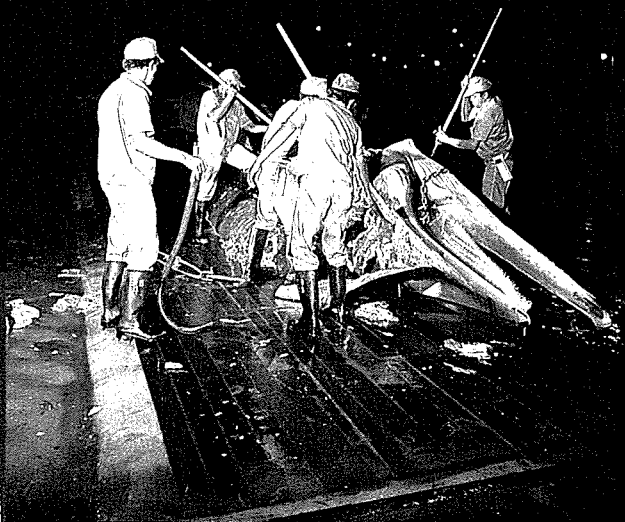
Dead whales are winched on to a factory ship's cutting-up deck where the blubber and meat are ripped from the carcasses.

Killer whales can reach a length of 9.5 metres and weigh 4,500 kg. They are fierce predators, feeding on fish, seals and even other whales.

THE FIRST WHALES APPEARED some 50 million years ago. But in the last century Man has hunted these magnificent aquatic creatures to the brink of extinction.

Whales are not fish. They belong to the unique class of air-breathing, sea-going mammals known as cetaceans. They are warm-blooded and the females give birth to live young that feed on their mothers' milk for the first months of their lives.

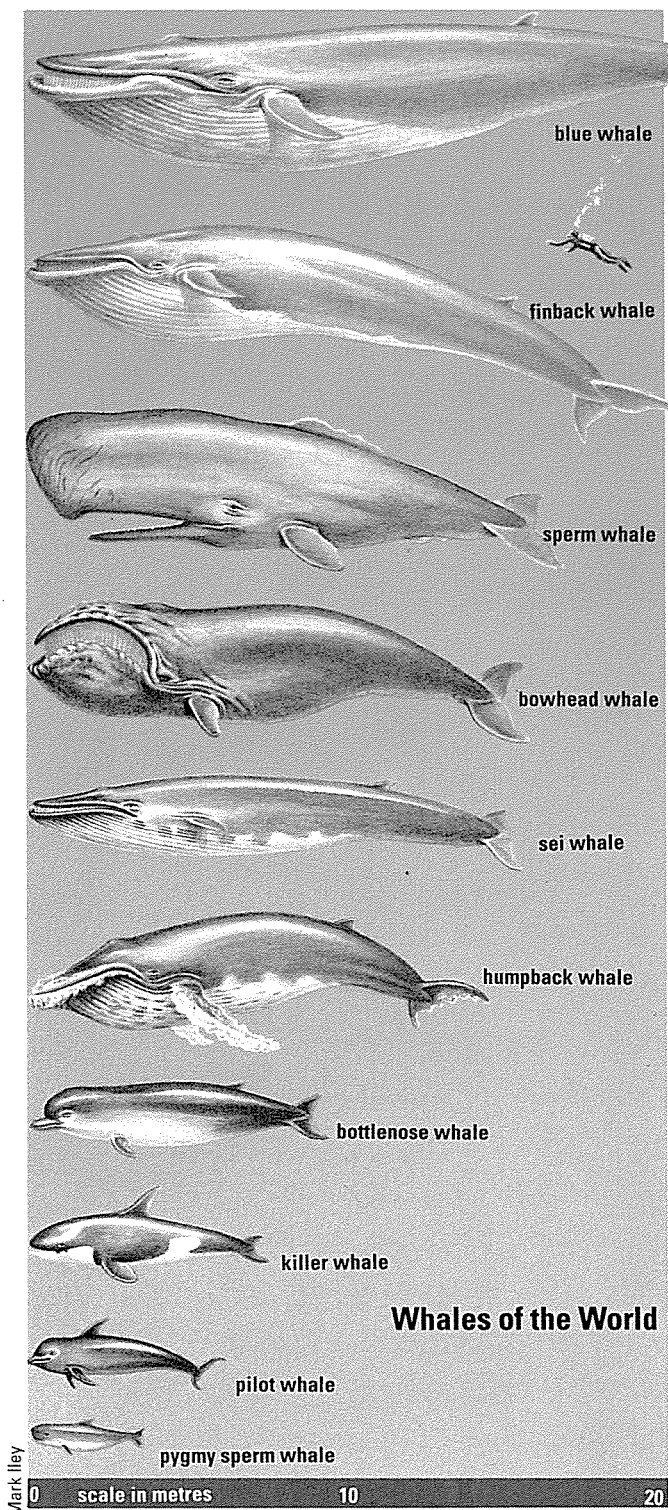
Whales are divided into two categories - *baleen* whales (which do not have teeth) and *odontoceti* (which do). Baleen whales, such as the grey, right, bowhead, fin and humpback whales, have developed large mouths capable of taking in massive quantities of food. Suspended from the upper jaw is a



ZEFA

Jeff Froot/Bruce Coleman Ltd





Whales of the World

row of triangular plates. These are made of baleen, a horny substance like stiff hair. Baleen plates act as a filter through which the whale strains its food as it moves through the water. Species such as the blue, minke and fin whales force water through the filter with their tongues, and swallow the creatures left behind.

Toothed whales

Toothed whales, which include the sperm, pilot, orca, beluga and beaked whales, have teeth which number between two and 300. These whales use their large teeth to grab squid and small fish, which they then swallow whole.

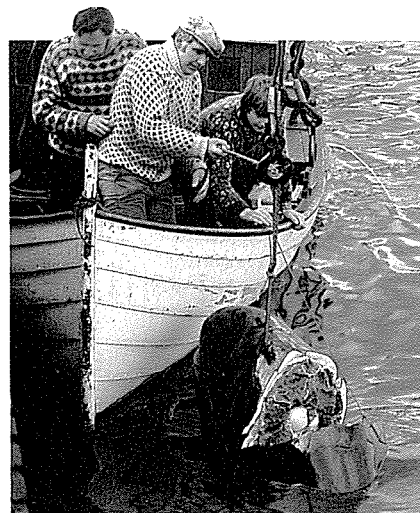
P. Morris/Ardea London

Faeroe islanders slaughter hundreds of pilot whales every year.

Fishermen drive the whales inshore by disturbing the water with oars, then stab or lance them through the neck. The meat is distributed to each islander. The whale slaughter once saved communities from starvation, but is now carried on as a tradition.

Whales are extremely varied in size and shape. The blue whale grows to over 30 metres and weighs about 160 tonnes. This is about twenty-five times heavier than the African elephant. The sperm whale is the largest of the toothed whales. Its huge head makes up 25-33 per cent of its body length.

Whalemeat is cut into blocks at an Icelandic station. Most of the meat is exported to the Far East. Iceland, Japan and Norway continue whaling for 'research' purposes but still sell the meat for profit. Eskimo communities are allowed to catch whales for subsistence purposes.



P. Morris/Ardea London

Toothed whales hunt and navigate using echo-location, or sonar rather like a submarine. They send out very high pulses of sound, or clicks, which last for only a fraction of a millisecond. The returning echo enables the whale to pinpoint an object and to calculate its own position in relation to the seabed and surface. Whales also use sound to communicate with each other.

Blow-hole

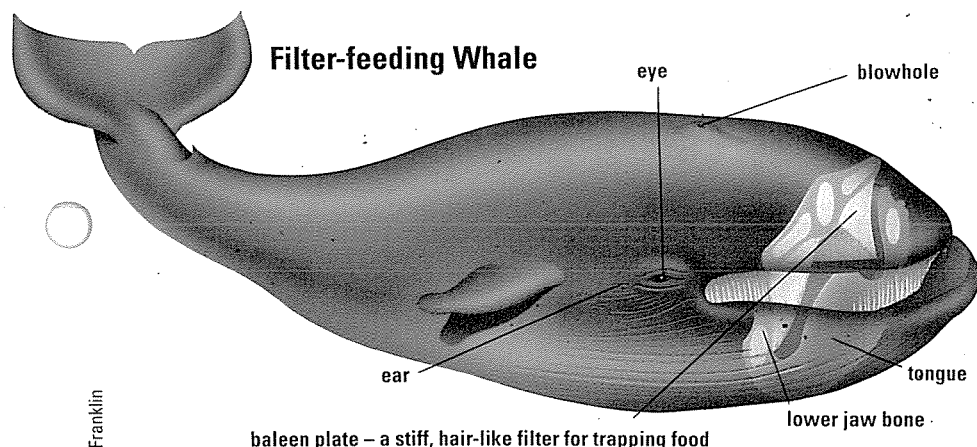
All whales breathe through a blow-hole at the top of their head. They exhale the stale air as soon as their head breaks the water's surface, creating the characteristic spout that hangs in the air for several seconds.

Whales were traditionally hunted for their blubber which was steamed



Dr Eckart Pott/Bruce Coleman Ltd





Mark Franklin

Baleen whales feed by filtering plankton through fibres attached to a plate in their upper jaws. Blue whales can take in 60 tonnes of water in one gulp.

and melted down to make soap, fuel oil, printing ink, margarine and industrial lubricants. These days, hunters are after prime cuts of whale meat - the outer layer of skin and meat, known as *muktuk* by eskimos. Some species, such as the narwhal, are hunted for the ivory in their tusks. This is used to make ornaments. The rest of the carcass is discarded.

All whales will help another

cable to the dead whale and tows the carcass back to the ship.

The problem with this system of whaling is that it is too efficient. Many whale species have had their numbers depleted to the point from which they will never recover. Even the bowhead, which haunts the waters of the Arctic, has had its numbers reduced to just five per cent of the original population. Commercial whaling peaked between 1961 and 1962 when around 67,000 whales were slaughtered. So many young whales and nursing mothers were

that whaling is no longer commercially viable.

Other nations have continued whaling because the ban has a loophole: so-called 'scientific' whaling. The International Whaling Commission still allows whales to be killed for 'scientific research'. But the meat from dead whales can still be sold as food.

Iceland has a 'research' programme that calls for an annual kill of 200 whales a year. Some 90 per cent of the meat is exported to Japan.

The Japanese themselves slaughtered 273 whales in 1987.

J Reditt/Hutchison Library



Whalemeat on sale at a market in South Korea. Some countries still hunt whales for food despite the international ban.

They are also seeking to have smaller-scale coastal whaling exempted from the commercial whaling ban. They want to be allowed to kill over 200 minke whales each year.

MODERN WAYS OF WATCHING WHALES



Tony Martin

Radio-tagging is an effective way of monitoring whales' movements. Transmitters are attached to the whale's back so that ships, aircraft or satellites can pick up signals from the ocean. In this way, research scientists can find out more about the migration routes of different species. Schools of humpback whales, for instance, travel vast distances from summer breeding grounds in the North Atlantic, to winter breeding grounds in warmer waters. Male and female sperm whales, on the other hand, separate after mating.

wounded whale, which makes them easy prey for hunters. Once one animal is harpooned, others gather round, making them easy targets. Modern-day whalers hunt their prey in motor boats called whale catchers or whale killers. Spotter planes direct them into schools of whales. A steel harpoon with a grenade at its tip is fired from a cannon at around 96 km/h. When the grenade penetrates the whale's hide, it explodes, firing steel barbs into the whale's flesh. It can take a fully grown whale up to half an hour to die this way.

Carcass collection

The carcass is then filled with air, marked with flags and left for collection by the factory ship while the whale killer heads off in search of more prey. The factory ship sends out a tug boat which attaches a steel

killed that future catches could only decline.

In 1972, the United Nations recommended a ten-year halt to commercial whaling for stocks to recover, but the International Whaling Commission which regulates the hunting of whales rejected the proposal - despite the fact that the average annual kill had dropped to 50,000. It was not until 1985 that the International Whaling Commission decided to forbid commercial whaling until 1990, when the ban would be reviewed.

Slaughter continues

But this has not stopped the slaughter. Japan, Norway, Iceland and the Soviet Union continued whaling and since 1985 more than 11,000 whales have been killed. The Soviets have now stopped because stocks of most species are so low

Just amazing!

HARD TO SWALLOW

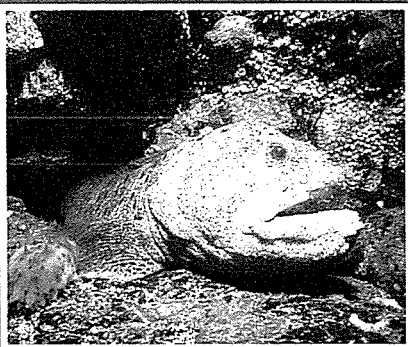
A DAY AFTER FALLING OVERBOARD NEAR THE FALKLANDS, SEAMAN JAMES BARTLEY WAS RESCUED FROM THE BELLY OF A WHALE. HIS ONLY INJURY WAS WRINKLES CAUSED BY THE WHALE'S DIGESTIVE JUICE.



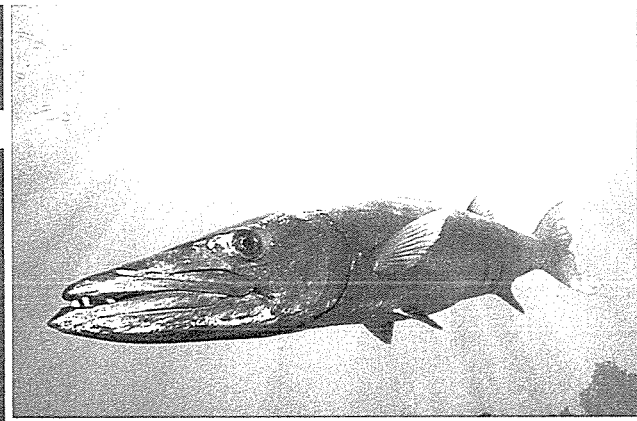
Paul Raymond



Ron & Valerie Taylor/Ardea London



The Pacific wolf is a spiny-rayed fish that can grow up to 2 metres in length. It feeds off the west coast of America, feeding on shell-shelled creatures such as oysters and clams.



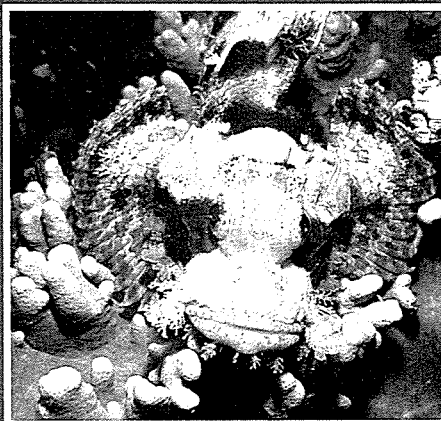
Kurt Amster/Photo Search Pictures

Barracudas are voracious, endless predators that have been known to attack humans. They usually lurk at the edges of corals reefs and wait for prey fish to appear.

Moray eels are among the most feared of the sea's predators. They hunt at night and retire to crevices by day. Morays have been known to catch fish from a shark's jaws.

Mantis shrimps seize their prey with a lightning movement of their jack-knife claws. Mantis shrimps will also attack their own species, but rarely do so as injury.

Scorpion fish have poisonous spines that inflict painful, sometimes deadly wounds in their prey. Their colourful, coral-like camouflage helps them blend in with the seabed.



Ron & Valerie Taylor/Ardea London

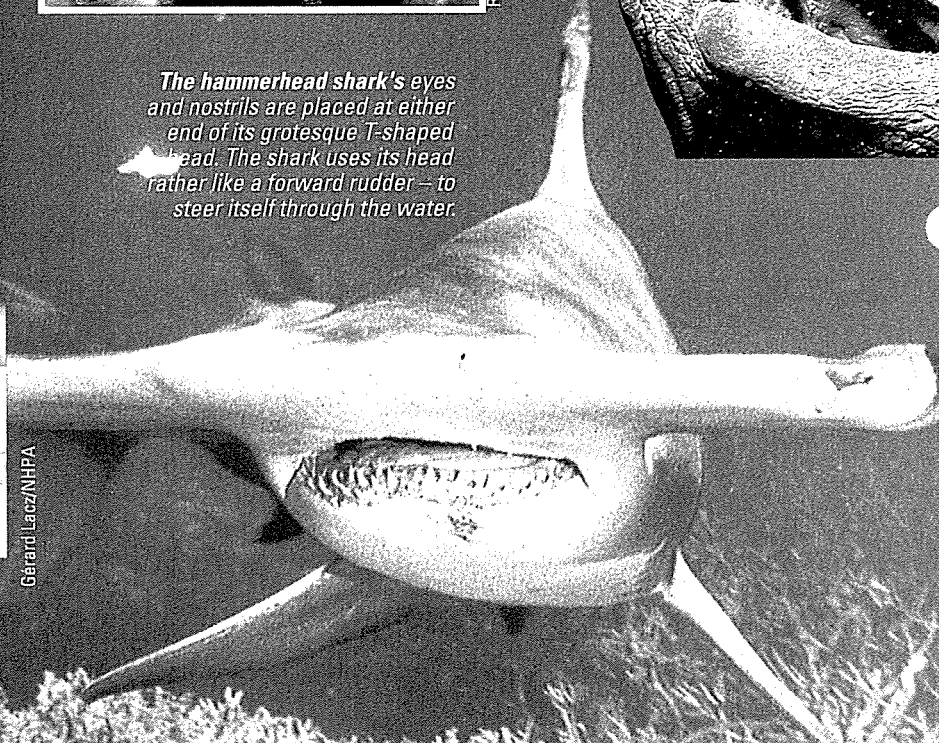
The hammerhead shark's eyes and nostrils are placed at either end of its grotesque T-shaped head. The shark uses its head rather like a forward rudder – to steer itself through the water.



Ron & Valerie Taylor/Ardea London

Sea snakes are highly poisonous – some with venom hundreds of times more potent than that of the cobra snake. The venom paralyzes the nervous system and the victim soon dies of suffocation.

Gérard Lacz/NHPA



Ron & Valerie Taylor/Ardea London



Skink-like rays have a skin-like covering on the back of their tail. The ray uses its tail at prey, inflicting serious wounds and immobilizing them with poison. Other species of ray kill prey by delivering an electric shock.



GROWING STRUCTURES

PLANTS PROVIDE A SUPERB example of living engineering, from their roots, which seek out water and minerals in the soil, to their leaves, which capture the energy of sunlight.

The green in the leaves and stems of most plants is caused by a remarkable chemical called chlorophyll. This is the vital substance that enables plants to trap energy from the Sun and use it in a process known as photosynthesis.

Water and minerals enter the plant through its roots, then travel up the stem through a series of fine tubes. These tubes eventually run out into the leaves via a network of veins

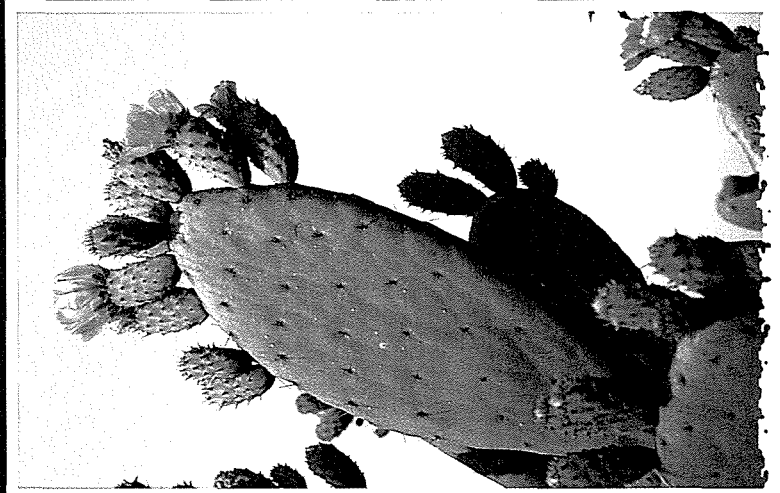
Cacti have thick-walled cells (magnified, far left) to provide support for their robust stems. Thick, leathery skin prevents water loss, and sharp spines, instead of leaves, protect the plant from grazing animals.

On the underside of a leaf are many tiny openings, or stomata, through which carbon dioxide from the air can enter. The leaf's upper surface, where the cells are very rich in chlorophyll, acts like a tiny solar panel. Having trapped the Sun's energy, the plant uses it to convert carbon dioxide and water into glucose - a type of sugar - and oxygen. The glucose then serves as an internal energy store to help the plant manufacture still more complex substances, such as proteins, that it needs to live and grow.

Plant structure

As well as being an efficient miniature factory, a plant is also a brilliantly engineered structure. Its stem and roots serve the dual purpose of transporting fluids and of supporting the leaves and other important parts, such as flowers and fruits.

Roots come in a variety of forms.



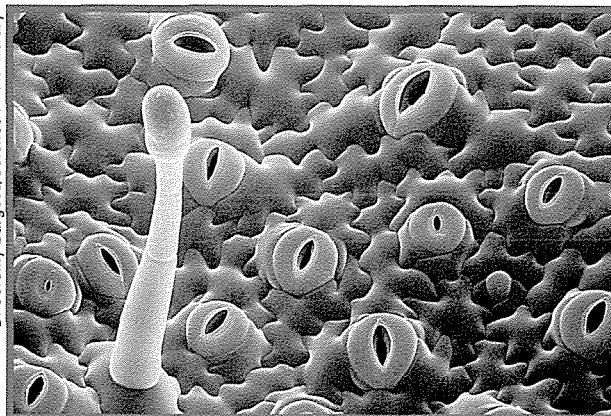
S & J Walter Science Photo Library



A tap root, for example, is a single, large root that anchors the plant and from which smaller, secondary roots grow. In the case of a carrot plant, the tap root is the entire orange part that we eat. A fibrous root system, on the other hand, such as that of grass or sagurro cactus, consists of a large number of equal-sized roots.

Other types of plant, such as ivy, have roots below and above ground level. These climbing, aerial roots are

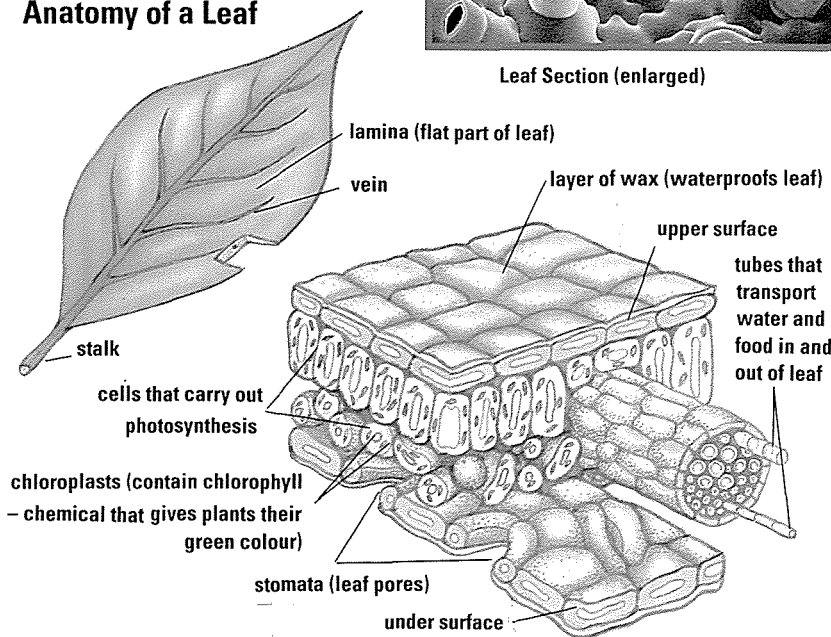
Dr. Jeremy Burgess/Science Photo Library



Leaf Section (enlarged)

Plants need sunlight, carbon dioxide and water to make food. This process – called photosynthesis – takes place in the leaves. Energy from sunlight is absorbed by chlorophyll. Carbon dioxide enters through tiny pores, or stomata, on the underside of the leaf (magnified left, 100 times). Water from the soil rises up via tubes in the stem.

Anatomy of a Leaf



often capable of absorbing moisture from the air - another instance of a plant structure doing more than one job. A fourth kind of root, called a prop root, grows down from a stem and then into the ground. This gives extra support and anchorage to plants such as mangroves, which are common in shallow tropical coastal waters.

Many of the most cleverly engineered parts of a plant are

concerned with reproduction. Plants have a bewildering number of ways to ensure that copies of themselves are made and that their species continues to survive.



Pollination

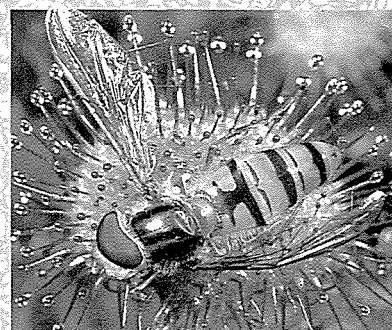
Flowers containing the male and female reproductive parts, are frequently coloured or scented to attract certain kinds of insects. The flower provides not only a landing pad but also a sweet substance called nectar that bees and butterflies feed upon. Unknowingly, the insects also pollinate the flowers. They do this by transferring pollen

grains from the male organs, or stamens, of one flower to the female organs, known as carpels or pistils, of another.

Once pollinated, the female structure begins to develop into a fruit containing one or more seeds. Essentially, the fruit is a vehicle to help the seeds inside it find a place where they can grow. Some fruits, like those of the broom plant, literally explode, shooting the seeds out.

INSECT EATERS

John Houghton



Claude Nuridsany & Marie Perennu/SPL

Some plants, such as the venus fly trap and the sundew plant (above), are carnivorous. The sundew lures insects with glistening droplets at the tips of its tentacles. As the victim struggles to escape, the sticky tentacles curl over, gluing it to the leaf. Enzymes digest the meal and the products are absorbed by the leaf. It takes a sundew a whole day to eat a single mosquito.

Poppy capsules, on the other hand, have tiny holes in the top like a pepper shaker, so that they release seeds whenever the wind blows them. Others, such as the bramble or apple tree, produce fruits which are eaten by a variety of animals. The seeds cannot be digested and are passed out in droppings, usually far away from the parent plant.

The seeds of the wild geranium are dispersed by mechanical means. Strips of fibre wind themselves around the spear-like seed pods. This causes the seed to become detached from the geranium's flower and to be dispersed by the wind.

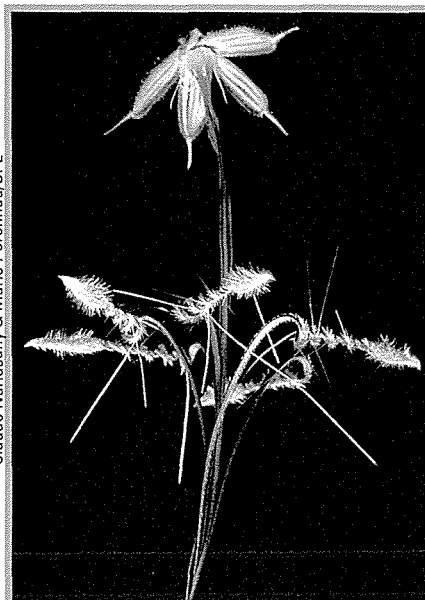
Just amazing!

ROOTS THAT RUN RIOT

UP TO 350 PROP ROOTS HANG DOWN FROM INDIAN BANYAN TREES, MAKING THEM WIDE ENOUGH TO COVER AN ENTIRE MARKET PLACE!



Claude Nuridsany & Marie Perennu/SPL



Paul Raymonde



TRAINING HOUNDS

STAG HUNTING

SHOTGUNS

HUNT

THE HUNTING CRUELTY debate is one of the most bitter controversial areas in sport. To some, stalking and killing their chosen quarry is not only enjoyable, but essential to preserving wildlife's natural balance. Yet others see blood sports as cruel and unnecessary.

Of all the blood sports, fox-hunting arouses the most passion – both for and against. Foxes are hunted as vermin and for their pelts in many European countries. But in Britain, the US and Australia, foxhunting has developed as a fieldsport – carried out on horseback and with a pack of hounds. Huntsmen claim that fox-hunting is not cruel, as the hound will snap the fox's spinal cord with its first bite, killing it instantly. But some people dispute this, claiming that the fox suffers a lingering, painful, death.

Training the pack

Foxhounds are trained from birth to hunt and kill, and do not make good pets – they have been known to turn on people. Between February and May of each year, new litters of hounds are bred. They are fed on a basic diet of porridge and meat, which may include 'fallen stock' –

Foxhounds are controlled by 'whippers-in' who try to prevent the pack from straying off to chase other animals or crossing busy roads.

dead cows and sheep from local farms. At the age of eight to ten weeks they are taken to farms where they are allowed to roam and play. During the following summer, kennel staff take the pack out for walks through country lanes and across fields. At this stage the hounds will be 'on couples' – two collars connected by a chain that is used to link the hounds in pairs. A young hound is partnered with an experienced old hound. In this way he learns what the various commands mean and becomes more disciplined.

In the course of the summer the daily distances increase. Packs are

The harder a fox runs, the more scent it gives off from its glands and pads. But only one out of every four hunts ends with a fox being caught and killed.

League Against Cruel Sports

Just amazing!

FIGHTING FISH

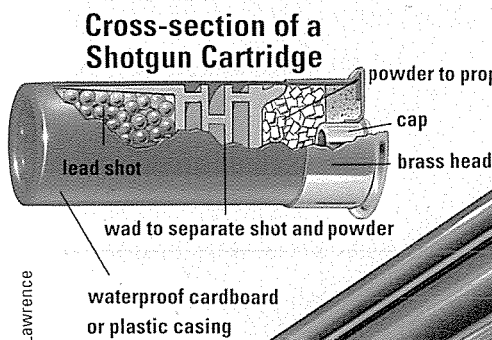
NEW ZEALANDER DONAL HEATLEY
TUSSELED WITH A 6-METRE LONG BLACK
MARLIN FOR OVER 32 HOURS IN 1968.
THE FISH DRAGGED HIS LAUNCH 80KM
BEFORE BREAKING THE LINE!



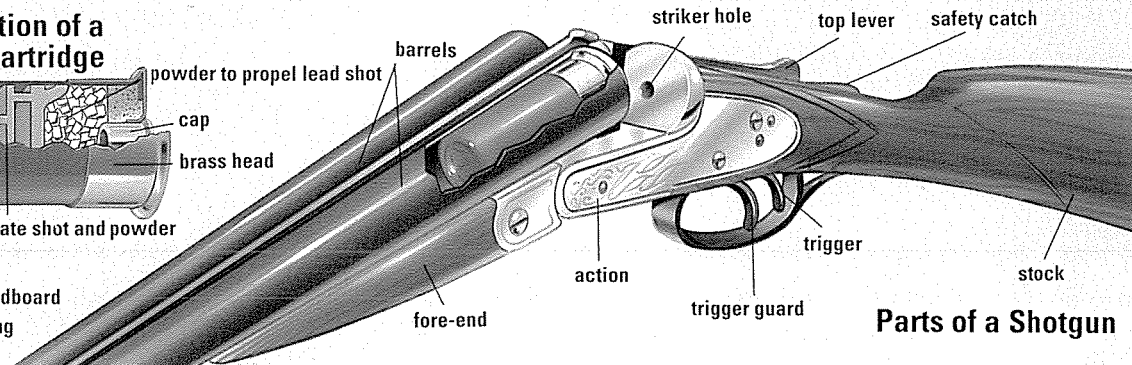
Paul Raymond



Cross-section of a Shotgun Cartridge

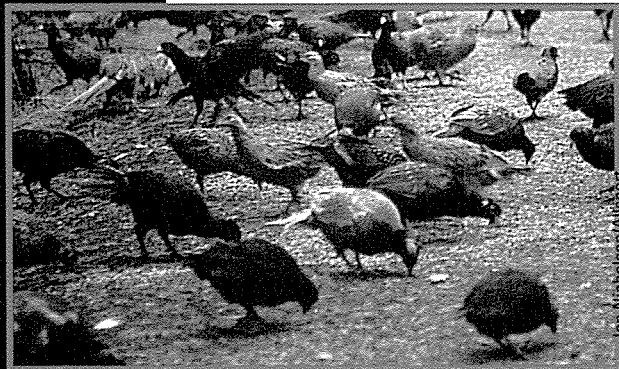


Joe Lawrence



Parts of a Shotgun

Most shotguns fire about 300 pellets (total 28 gm) with each shot. The range is usually not much more than 30 metres.



Jon Nicholson/Allsport

Game birds are 'hung' for about a week before being eaten. Bacteria makes the flesh more tender – and smelly!

in Britain, where the animal is now a protected species. It has been replaced by the hunting of wild mink, a vicious animal that feeds on chicks and eggs.

Just as controversial is deer hunting, which is still carried on in many European countries. In Britain this once took the form of 'carted' stag hunting, where a deer was selected from a domesticated herd – often from a private deer park – and driven to a 'meet'. The deer was then released to be chased by staghounds, followed by hunters on horseback. When the hounds caught up, they would not kill the deer but surround it and bay. The hunters would then return it. But stag hunting today usually ends with the slaughter of the deer and the distribution of

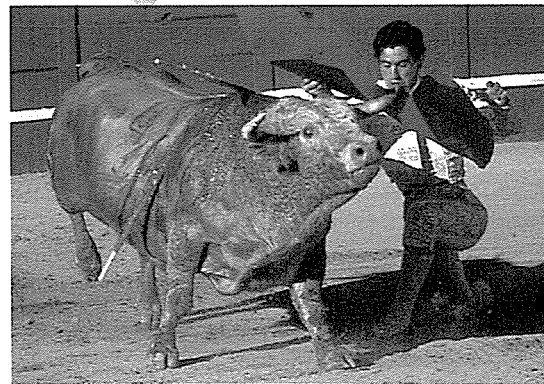
Jon Nicholson/Allsport

DEER HUNTING

Farmers in Europe defend the hunting of wild deer because they cause damage to trees and crops. Stags grow a new set of antlers every year. As these begin to harden they irritate the animal, which then rubs them against trees. This can strip the bark off a tree so badly it can die. Wild deer also cause crop damage, eating root vegetables and flattening fields of corn.

When the numbers of deer rise to an unacceptable level, they have to be cut back (or culled) and this is where the hunters come in. They use special hounds called tufters that chase the chosen stag away from the herd to start the hunt. When the hounds catch the stag, they surround it until the hunters arrive. It is then shot and taken away to be butchered.

In Spanish bullfights, the kill is by the matador thrusting a sword, known as an estoque, between the bull's shoulder blades, severing the aorta.



Vandystadt/Allsport

taken through farmyards, fields and villages to accustom them to different types of animal. Young hounds that stray from the pack to chase a sheep or cat are thrashed. A hound that consistently refuses to be trained will be put down. By autumn the pack should be fit, disciplined and ready to take part in cubhunting – the hunting of young fox litters which gives the young hounds their first taste of the hunt.

Huntsmen defend their sport by pointing out that foxes are carnivorous vermin that kill chickens and lambs and worry sheep.

Pest control

This 'pest control' argument is also used to defend the hunting of hares and minks by hounds such as harriers, beagles and otterhounds.

Otter-hunting has been outlawed

Electronic 'bleepers' attached to terriers' collars help locate them when flushing out foxes underground. The transmitters have a range of about 4.5 metres.

Bob Lawrence



its meat – venison. The hunters use a shotgun to shoot the deer at close range, killing it instantly. When a deer is tracked on foot – without the use of hounds – a high-powered rifle is used.

Grouse shooting in Scotland attracts hunters from around the world. The grouse are bred for shooting but are protected in the wild until the season opens on 12 August each year.

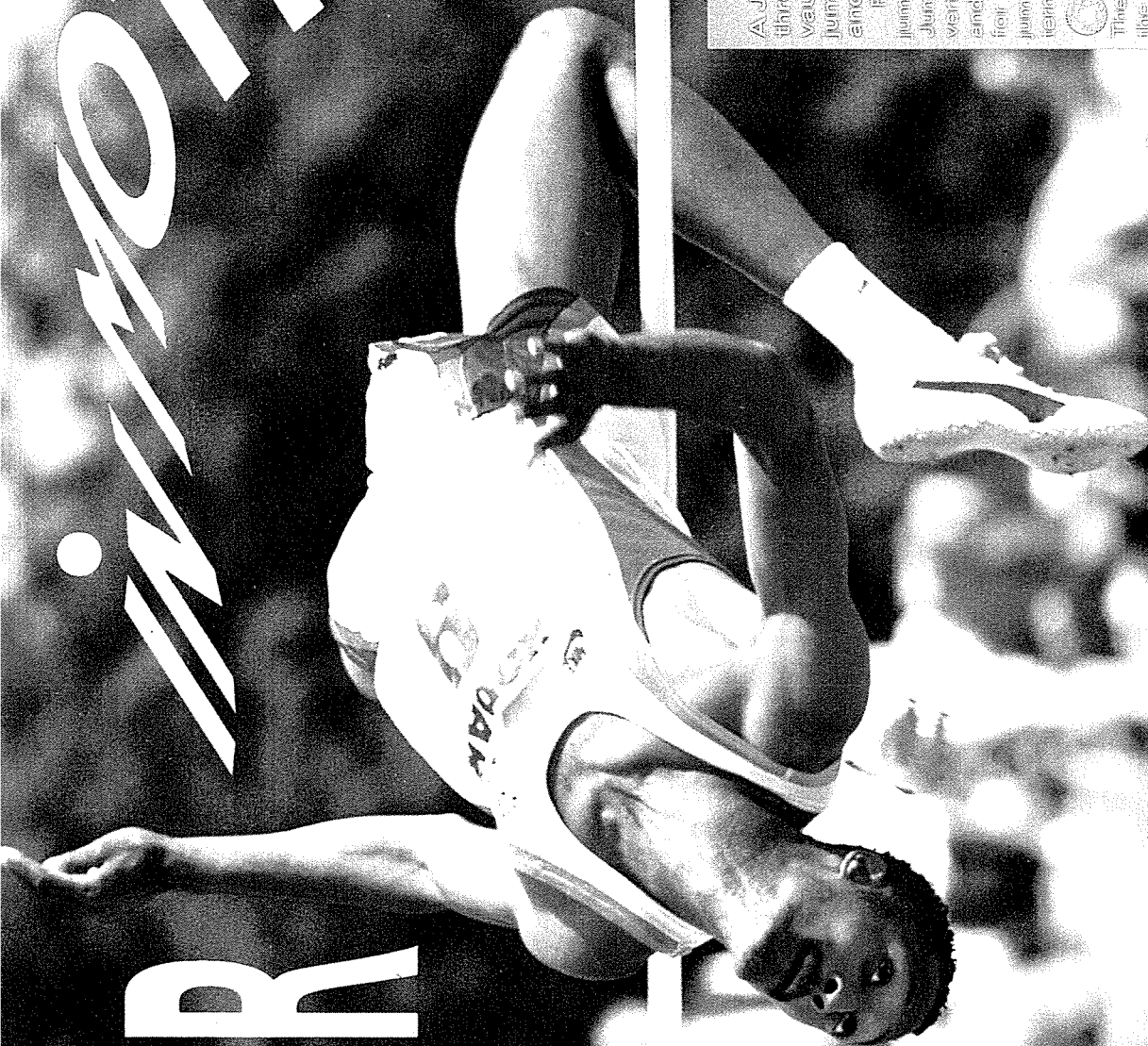
Then shooting parties advance on the moorlands with teams of 'beaters' ahead to chase the birds into the air. The sport is similar to clay pigeon shooting – except that the targets are live.



POWER

- JUMPING TECHNIQUES
- BODY TYPES
- ACCURATE MEASURING

IN MOTION



The 'Fosbury Flop' is a relatively simple high-jump technique because its movements in the air are bilateral (arms and legs move together in the same direction)

A JAVELIN ARCING 80 METRES through the air, a perfect pole vault or gravity-defying high jump – all require immense skill and athleticism.

Field athletics, comprising four jumping and four throwing events, jumping events may be divided into vertical jumps for height (high jump and pole vault) and horizontal jumps for distance (long jump and triple jump). They all follow the same pattern of run up, take off and landing.

Gravity and ballistics

The angle and speed of take-off and the trajectory (or flight path) of the athlete are vital to the success of the jump. The trajectory is determined by the position of the body at take-off, with the centre of mass being the body's centre of gravity. This needs to be further forward when jumping for clearance, and further back when trying for height. As the laws of gravity overcome the laws of ballistics come,

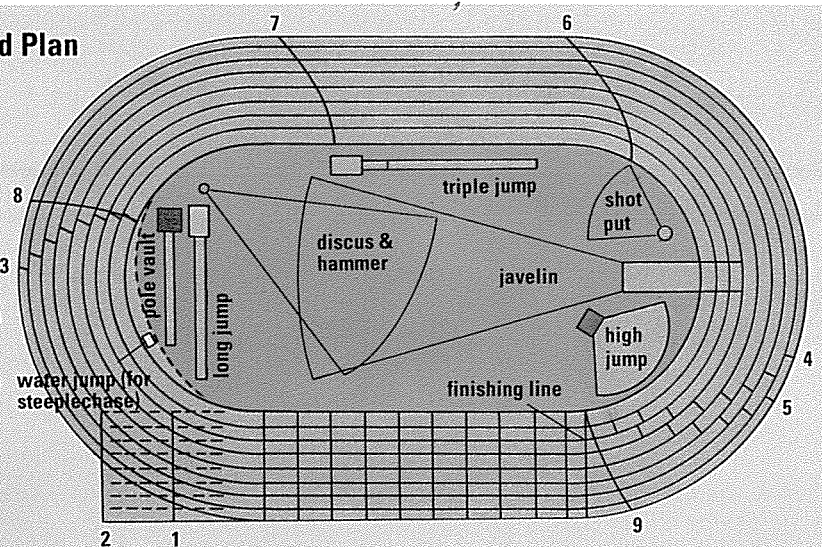


Athletics Ground Plan

Starting lines for track events:

- 1 100m & 100m hurdles
- 2 110m hurdles
- 3 200m
- 4 400m & 400m hurdles
- 5 800m
- 6 1500m
- 7 3000m steeplechase
- 8 5000m
- 9 10,000m

Mark Franklin



into effect. When jumping for distance, horizontal force is most important, whereas in high jumping, upward thrust is the main aim.

High-jump styles

There are several types of high jump, including the straddle, the Western roll and the Eastern cut-off – all of which involve clearing the bar with the body parallel to it. But the event was revolutionized in the 1960s by Dick Fosbury, who introduced the famous 'Fosbury Flop'. This involves

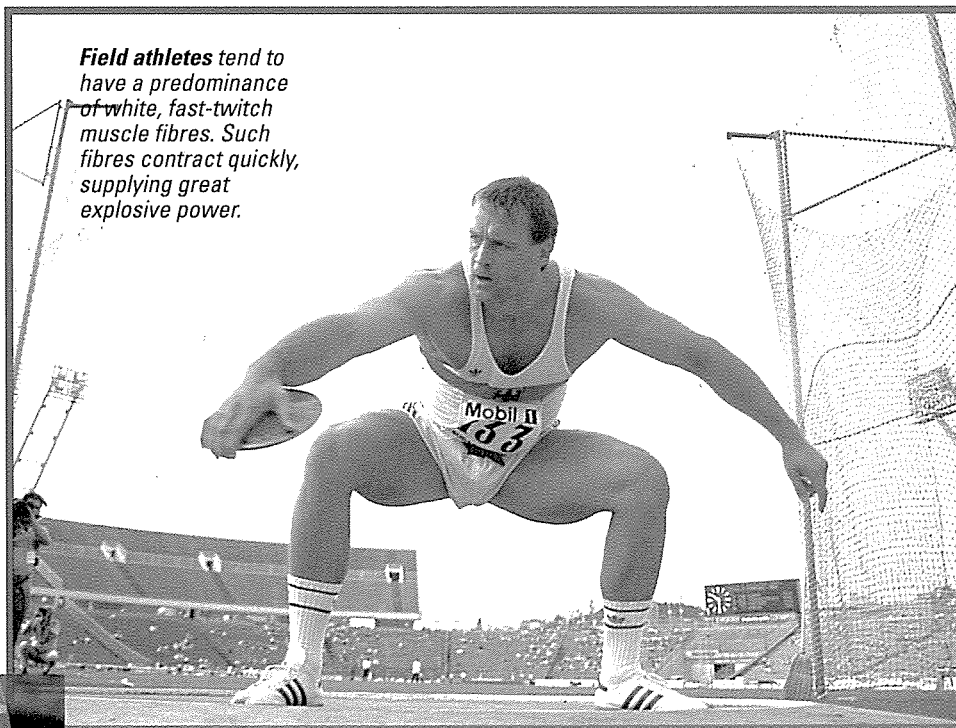
A bird's-eye view of a typical athletics field shows the importance of scheduling the events of a big meet. Athletes, officials, support staff, television crews and reporters must all be co-ordinated.

Record-breaking athlete Jackie Joyner-Kersey of the USA launches a shot. She holds the world heptathlon record – the ladies combined event of 100 m, 200 m, 800 m, hurdles, high jump, long jump, shot and javelin.



Weight training, throwing practice and short sprints are major elements in Steve Backley's year-round training programme. The UK's greatest-ever javelin thrower, Backley threw a record 85.9 metres at the World Cup in Barcelona, in 1989.

Field athletes tend to have a predominance of white, fast-twitch muscle fibres. Such fibres contract quickly, supplying great explosive power.



leaping head first at the bar and twisting in mid-air, so that the front of the body faces upwards. It may sound complicated, but it has allowed men to clear a new world record of 2.43 metres, and women to clear a new world record of 2.09 metres. Pole vaulters can reach much greater heights – the world record is over 6 metres – helped by a flexible fibre-glass pole, which acts as a spring.

For long and triple jumping, maximum speed at take-off is vital. The run-up may be 50 metres long, so that the jumper can hit the take-off board at top speed. It is not surprising, therefore, that top sprinters such as Carl Lewis also make good long jumpers.

The triple jump is really a variation on the long jump, but where the athlete takes off from a board further



BREAKING POINT



David Cannon/Allsport

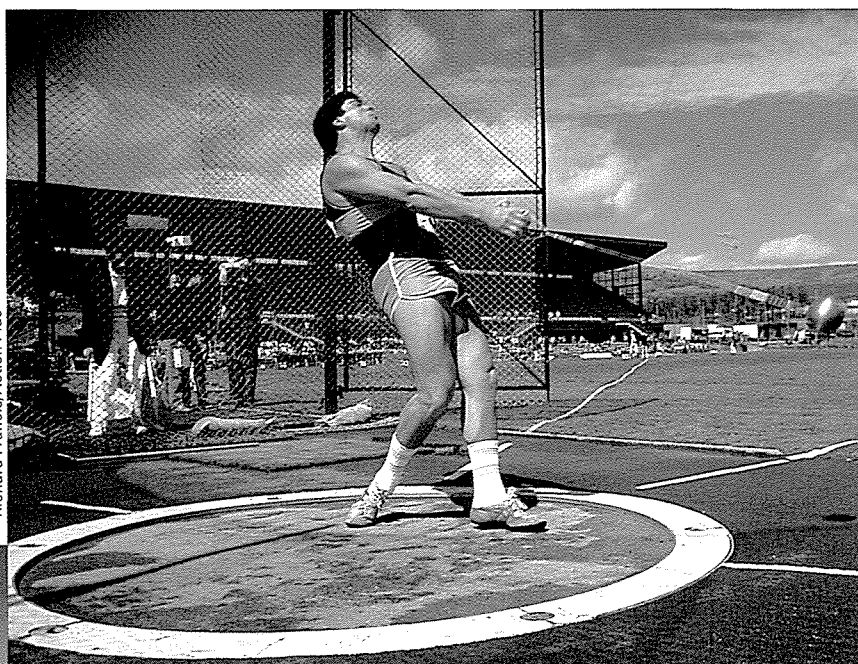
Traditional wooden poles for pole vaulting have been replaced with fibreglass poles that are more flexible – but they do occasionally snap under pressure. This happened to Olympic decathlon champion Daley Thompson at the 1988 Olympic Games in Seoul.

from the pit. He is then permitted to land on one foot, push off and land on the other foot before making his leap into the pit. As in the long jump, it is the first mark in the sand that is measured from take-off.

Athletic physique

For all jumping events, the athlete needs great power in the lower body and legs, plus agility, flexibility and the ability to 'spring'. Studies show that taller people tend to have greater strength potential in proportion to their size, and greater respiratory capacity. Shorter people are faster to accelerate and are better able to lift their own body weight. Most jumpers tend to be tall and long-limbed. Such a build means that the athlete's centre

Richard Francis/Action Plus

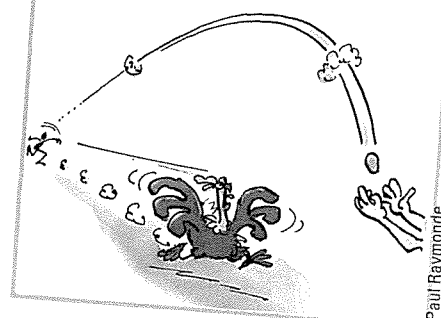


The body is angled further from the vertical when releasing a hammer than for other throws. Hammers weigh 7.26 kg. The head (left) is usually of iron filled with lead.

Just amazing!

LONG RANGE EGGS

FIELD-THROWING RECORDS CANNOT BEAT THE 96.9 METRES THAT FINLAND'S RIST ANTIKAINEN THREW A FRESH HEN'S EGG TO A FRIEND IN 1981 - WITHOUT BREAKING IT!



Paul Raymond

of gravity is higher while long limbs give extra leverage and 'spring'.

Throwers tend to be solid and heavily-muscled. Their initial force, when throwing, is achieved by the strength of the legs, which transmit energy through the body to the arms. Good musculature is absolutely essential because it gives throwers power and a solid base to work from. But this can lead some athletes to building a physique more in keeping with body building than athletics, and

some are rumoured to use illegal anabolic steroids to add muscle bulk.

Throwing events are divided into heavy throws (shot and hammer) and light throws (discus and javelin). But another classification can be linear (shot and javelin) or rotational (discus and hammer). In linear events, push (or impulse) is the main force, whereas in rotary throws, pull (or centripetal) force predominates.

Parameters for distance

The velocity of a thrown object at its moment of release is the most important factor in good distance throwing but many factors affect the length of a throw:

- velocity at release
- height at release
- angle of release
- the force of gravity
- aerodynamic shape of the object
- wind speed and direction
- ground reaction force

Throwing competitors must start

one and a half turns before launching. The hammer thrower will also swing the hammer in a circle above his head before he starts to turn, in order to gain full momentum.

Balance

Balance is of crucial importance to throwers, and is a particularly complicated matter for hammer throwers. The hammer is swung around the body to build up its speed before it is released. Because the mass of the hammer is less than the mass of the thrower, balance is maintained during these 'winds' by increasing the radius of rotation of the hammer. Thus the hammer covers a greater distance than the thrower while he spins. As the hammer gains speed the thrower uses the increasing centrifugal force to help maintain his balance. Throwing the hammer is the only field event in which women do not compete.

World records for the throws are huge distances – the men's records



for hammer, javelin and discus are all nearly 90 metres, while the women's records for discus and javelin are around 80 metres.

Traditionally, thrown distances of the shot put, hammer, discus and javelin are measured with a calibrated steel tape divided into centimetres. This is time-consuming – and inaccurate. For example, the tape may expand or contract slightly according to temperature. This will have a more noticeable effect on longer throws. Also, the ground level between the throwing circle and the hit point may not be equal.



Electronic measuring

Using an electro-optical tacheometer – a surveying instrument that rapidly measures distances – such inaccuracy

THE LAW OF A THIRD

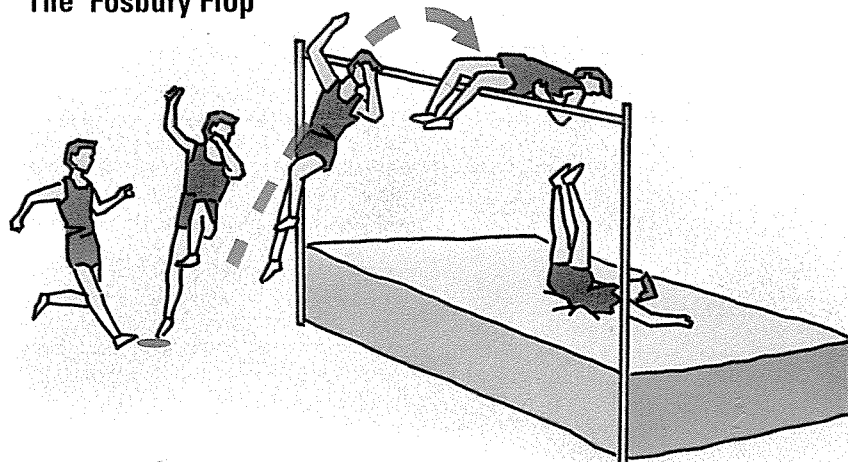
Women athletes often achieve their best results at an earlier age than men because their bodies mature more rapidly. The biological differences between men and women are taken into account by the International Amateur Athletic Federation. Their coaching manual suggests 'The Law of a Third' is suitable for women in training for running events:

- Reduce by one third, the total distance normally applicable to men
- Reduce by one third the number of fast intervals

cies can be minimized. The instrument takes measurements from a base line through the throwing circle, and from a reflector planted on the hit point by a judge. It calculates the thrown distance using the angle between the base line, the instrument itself and the hit point.

With long and triple jumps the reference points are the edge of the take-off board and, again, a reflector planted by a judge. The tacheometer calculates the distance jumped in about ten

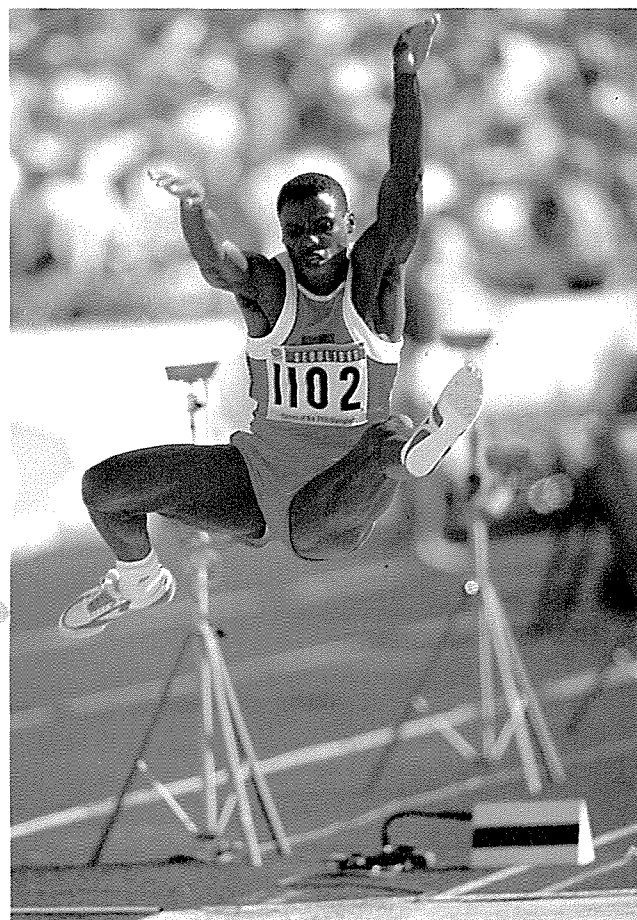
The 'Fosbury Flop'



Simon Critchley

This revolutionary high-jump style rotates the body around its own horizontal axis. The foot plant and turn stop the body's forward motion but keep it moving upwards – so the total force of the jump can be directed up into the air rather than towards the bar.

Carl Lewis adopts the 'hang' position during a long jump to maintain balance and prepare his landing position. The black and white marker is a reference for an electro-optical tacheometer (below). This machine takes a second reading from a reflector on the landing spot, then calculates the jump using known distances and angles.



Leo Mason/Split Second

seconds, and is accurate to 5 mm. Electronic measuring is especially useful for checking pole-vault measurements. Pole-vaulting athletes may ask for the uprights to be moved forward or backward (not more than 60 cm) from the stopboard to suit his or her style. Each time the uprights are moved or the bar is adjusted, the bar height is checked.

Television tie-up

Because they are in digital form, electronic measurements can be automatically relayed to field scoreboards, central computers, printers and character generators to be turned into video signals for displaying on television.

J N Hooker/City University



SKIN STRUCTURE

INSULATION

SCALY LAYERS

COVER-UP



THE VARIETY OF ANIMAL coverings is incredible: a porcupine's long spiny quills, a snail's shell and a sheep's woolly coat are only three. The main surface covering of an animal, however, is its skin.

Skin protects the organs inside the body and helps prevent disease-causing organisms from

entering. In many animals it is also a sense organ. The skin of a backboned animal, for example, contains sensors that detect touch, pain, heat and cold. In animals that live on land, the skin forms a waterproof layer that keeps water out while at the same time preventing the body from drying out.



Fantastic skin

In the most advanced, warm-blooded animals – birds and mammals – it helps keep the body at an even temperature. On warm days blood

vessels near the skin's surface expand and heat escapes through the skin. On cold days these blood vessels contract and slow down the cooling process by preventing blood from reaching the surface. Sweating also helps some mammals (Man, for example) to keep cool.

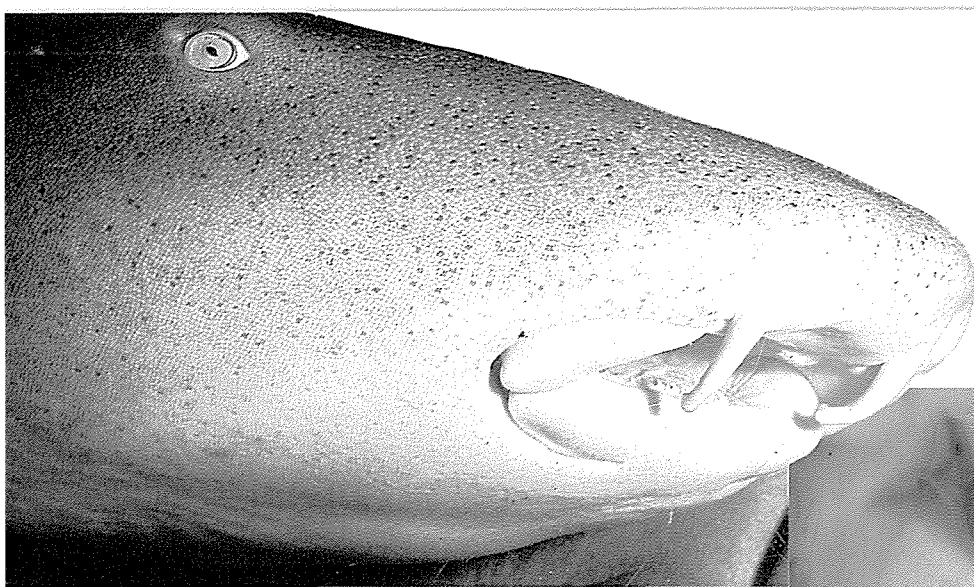


Insect armour

In invertebrate animals (animals without backbones) the skin is very simple, consisting of a single layer of cells. Sometimes there are additional features. The skin cells of an insect, for example, produce a hard outer layer, known as the cuticle, made of a substance called chitin. The whole structure is rigid, but elastic enough

The red-eyed tree frog, in the tropical rain forest of Central America, has a moist, slippery skin. A layer of mucus on the skin reduces the amount of water lost from the body.





derived from the dermis. Similarly, the scales of some lizards originate in the dermis, with a covering of horny material produced by the epidermis.

The scales of most reptiles, however, such as alligators and crocodiles, are produced entirely by the epidermis. This type of scale simply consists of a solid, flattened piece of keratin, or horn. The scales overlap



James Bell/Science Photo Library

Ken Lucas/Planet Earth Pictures

not to break easily.

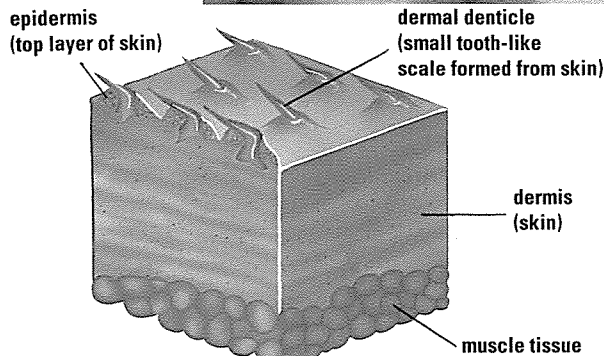
The skin of a vertebrate consists of two layers: an outer epidermis and an inner dermis, each of which is composed of several layers of cells. The epidermis is made of flat cells that are continually being renewed from below as the outer ones are rubbed

A shark's teeth are produced by the dermis (skin), as are the teeth of all animals with backbones. Each tooth has the same structure as scales on the shark's skin.

BLUBBER

Mammals that live in very cold climates use fat to insulate their bodies and keep their precious body heat inside. A polar bear, for example, has a layer of fat under the skin, as well as a thick fur coat. For animals that spend most or all of their time in cold water, good insulation is vital. Water must be kept out of fur, as wet fur soon allows heat to escape from the body. Fur seals and sea lions have a dense coat of waterproof fur, but they also have an insulating layer of fat, or blubber. However, in cold, wet conditions blubber is the more effective insulator. Whales, true seals and sea cows, with very little hair, rely on a thick layer of blubber under the skin to keep them warm.

Mark Franklin



Section Through Shark's Skin

Shark-skin is covered by sharp, tooth-like scales called denticles (magnified 150 times, above). Made mostly of enamel and dentine, they protect the body by acting as a kind of armour-plating.

Sweat glands in the skin cool the body when it gets too hot by secreting water. The water also contains waste products, such as salt and urea.

off. In land animals the outer cells of the epidermis are dead and filled with a substance known as keratin. This outer layer of dead cells provides the waterproofing that is so vital to land animals. In some places it forms thickened areas of skin, such as the warts of toads and toe pads of mammals.

In many animals, the skin cells produce definite structures on the surface of skin. The scales of sharks, for instance, and bony fishes are

and form a tough, waterproof layer on the outside of the body – something that is completely lacking in amphibians, the animal group from which reptiles evolved. Similar scales are also found on the legs of birds and on the tails of certain kinds of mammal, such as rodents.

Claws are also horny structures derived from the epidermis of the skin. These structures protect the tips of the digits

Vandystadt/Allsport





The mallard drake is insulated from the water by an undercovering of plumules, or down feathers. In addition, all adult birds have contour feathers (including flight and tail feathers) and fluffy filoplumes (below).

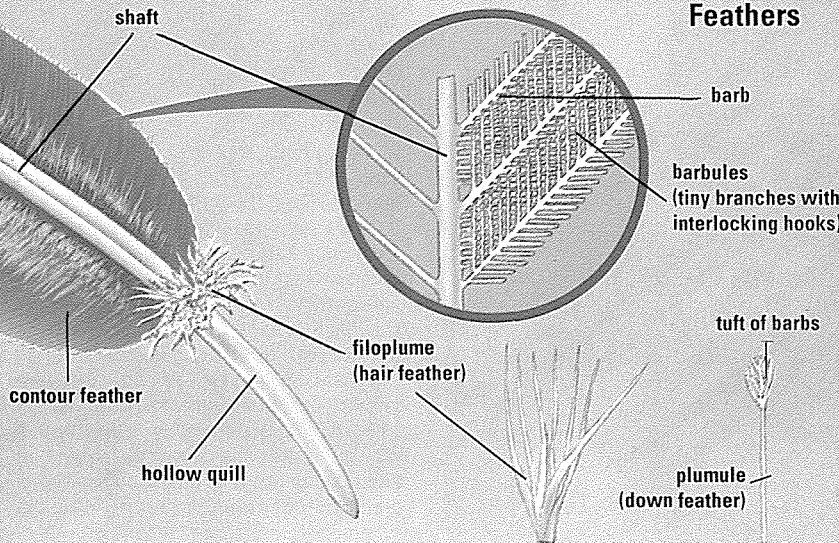
reptiles. Feathers help to keep birds warm and enable them to fly. Their colour is important for display or camouflage. A bird needs to keep warm because it is warm-blooded – that is, it maintains its body temperature using heat produced by chemical reactions



The potential elasticity of skin is demonstrated by the male great frigate bird, when he inflates a sac on his breast to attract a female to his nest site.

MP Harris/Nature Photographers Ltd

Feathers



(fingers and toes) and grow continuously from a special region of cells. In some animals, notably primates, claws are flattened into nails. In many grazing and browsing animals they have become hooves that are used for walking.

Growing horns

Some of these animals have horns, which consist of a central core of bone, surrounded by a horny sheath. True horns – those of cattle, for instance – are never shed, unlike the antlers of male deer, which are formed of bone. A young deer takes several years to develop a full set of

antlers, which are shed and regrown each year.

The body of a bird is covered with feathers. These, too, are produced by the epidermis. Scientists believe that feathers evolved from the scales of

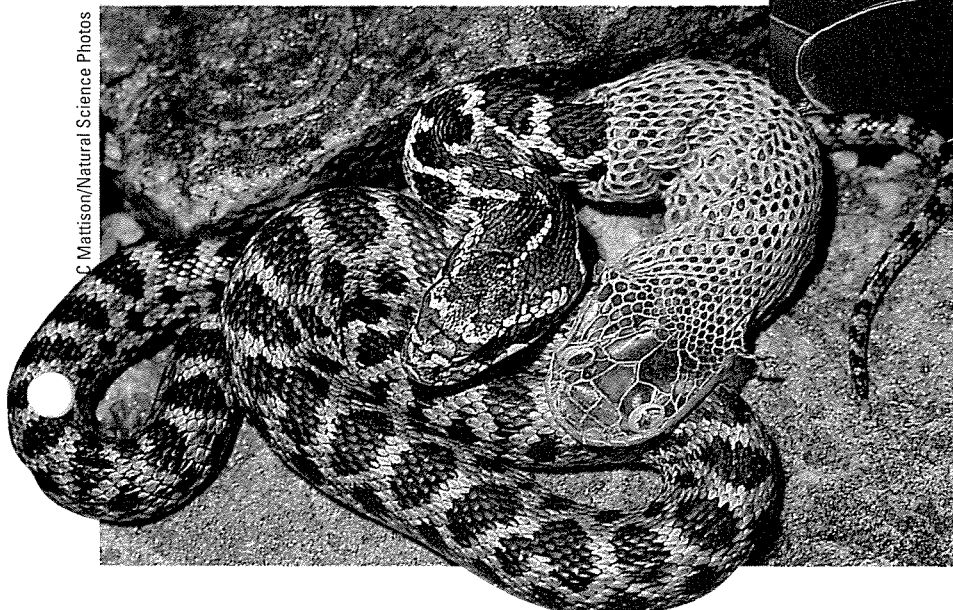
in its own body. Feathers make an excellent insulating material because they trap a layer of still air next to the body. In fact, feathers may well have originally evolved for this purpose. Only later did birds evolve a way of

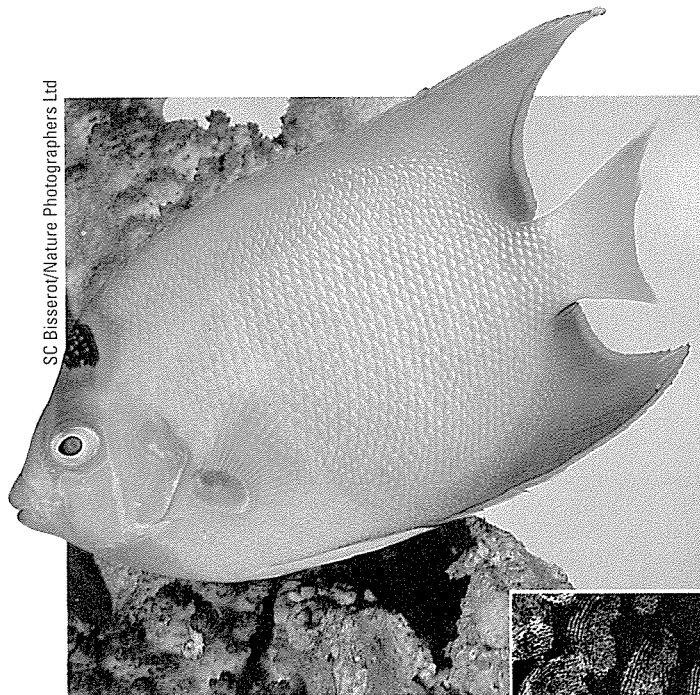
A four-lined snake sheds the horny outer covering of its skin in one piece. Overlapping scales of an Indian python (right) are made from horny keratin produced by the epidermis.



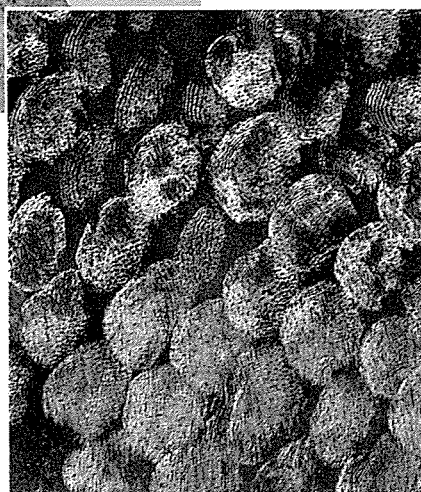
using them for flying.

Mammals are also warm-blooded and must keep warm. In this case it is hair, or fur, that provides the insulation; many hairs together, like feathers, trap a layer of still air next to the skin. Hairs, too, are produced by cells that form part of the epidermis. Made of keratin, they develop in deep pits, known as follicles, that lie buried in the dermis. Each hair follicle has a sebaceous gland, which produces an





Bony fish, such as the queen angel fish found in the Caribbean Sea, are covered with scales produced by the dermis, or skin. Those shown below (magnified three times) belong to the rainbow trout. Tiny crystals and pigment cells in the skin give the fish their colour.



Mark Mattock/Planet Earth Pictures

oily substance that keeps the surface of the skin supple.

Unlike feathers, hairs are not thought to have evolved from scales. In fact, hairs probably evolved before the reptile ancestors of mammals lost their scales, and there were probably some creatures that had scales with hairs growing in between them.

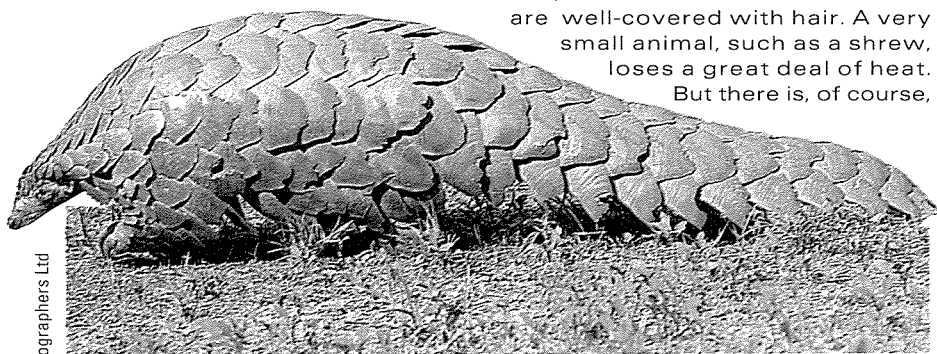
Hairy monsters

Today, mammals that use fur for insulation generally have two layers of hair. The inner layer is formed from a dense mat of fine hairs and provides most of the insulation. The outer layer is made up of thicker, longer hairs that are well supplied with oil and form a waterproof covering. This is vital for many animals as, if the inner layer gets wet, it loses its insulating properties and the animal may rapidly become too cold.

cause they have large bodies with thick skins. A large animal has a small area of body surface compared to its volume and loses relatively little of its body heat.

A smaller animal has a greater surface area in relation to its volume. It therefore loses more heat; because of this, most medium-sized mammals are well-covered with hair. A very small animal, such as a shrew, loses a great deal of heat.

But there is, of course,



Hugo van Lawick/Nature Photographers Ltd

The musk ox is well protected from the cold of North America's Arctic tundra by its two layers of hair. A shaggy outer coat of coarse hair with strands up to 62 cm long covers a fine underfur.

Little and large

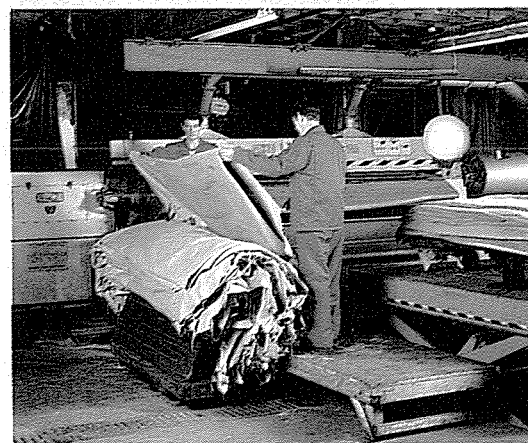
Not all animals use hair to keep warm. Elephants, rhinoceroses and hippopotamuses, for example, have a very sparse covering of hair. Such animals stay warm because they live in warm areas of the world, and be-

A Cape pangolin in Tanzania, Africa. Its horny, overlapping scales are formed from fused hairs. The pangolin is the only mammal covered with scales.

a limit to the thickness of hair such an animal can carry. The shrew maintains its body temperature by eating the equivalent of three-quarters of its own body weight each day.

Hair may be used for other purposes. A rhinoceros horn is not in fact a horn at all. It is a mass of hair-like

RECYCLING SKIN



Shoes, gloves, coats, saddles, luggage and chairs may all be made out of leather – the specially treated skins of animals such as pigs, goats, sheep, and especially cattle. A great deal of leather comes from cattle that have been slaughtered for meat. The skin is first stripped of its hair and cleaned. Its upper layer, or epidermis, may then be removed. Some skins are split into two or more thicknesses. Next, the hides are treated with chemicals to prevent them rotting – a process known as tanning. In one tanning process hides are soaked in a solution containing tannin, which is obtained from the bark, leaves or nuts of certain trees, such as the oak or quebracho (a hardwood from tropical America). Fats and oils make the hides supple. The hide is then shaved to the required thickness (shown above) and dyed.

British Leather Co Ltd

structures fused together. Rhinoceroses in Africa and tropical Asia have been brought to the point of extinction by hunters seeking their horns. The horns are mostly used to make dagger handles. In addition, many people believe (wrongly) that ground rhino horn is an aphrodisiac and has medicinal properties.

Just amazing!

SHAGGY SHEEP STORY
EACH YEAR A MERINO SHEEP GROWS ENOUGH WOOL TO PRODUCE A STRAND OF YARN 3,500 METRES LONG - LONGER THAN TEN AIRCRAFT CARRIERS PLACED END TO END.



Paul Raymond



SURVIVAL STRATEGIES

Inquisitive as a leaf
or a flower,
insects use strategy
to escape. This
leaf beetle
goes so far as to
pretend to be a dead
leaf, which does
make good things of all.

These snake eyes
are just a disguise
for the tail of
the hawk moths
a caterpillar mimics
the head of a snake
so that a predator
such as a bird, will
think twice
before attacking.

DECEPTION IS A VITAL
tactic used by both predators
and prey in the battle for
survival. Many animals deceive
others into believing either
that they are not there, or that
they are something else, or
even that they are dead.

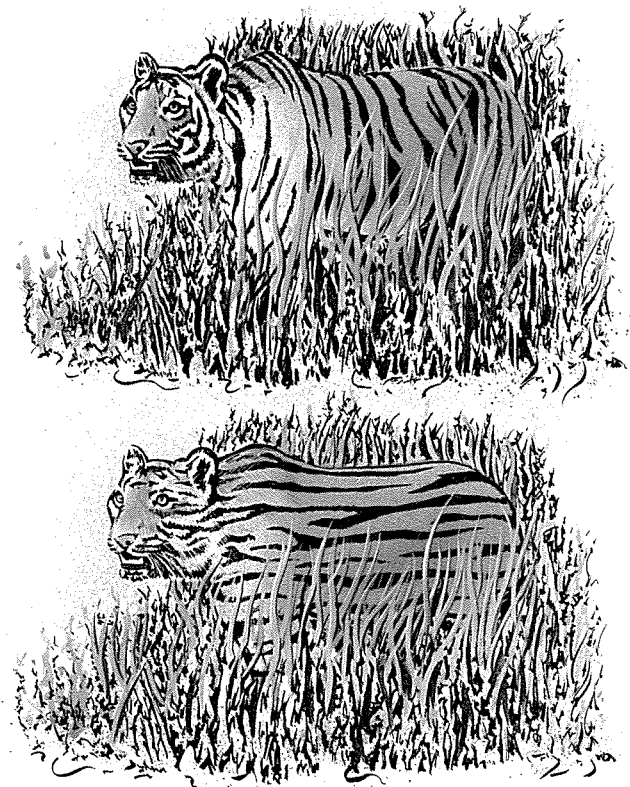
The most common form of decep-
tion is camouflage. By blending into
its surroundings, an animal can be-
come part of the landscape, virtually
invisible. Many tiny, transparent sea
animals, for example, are nearly im-
possible to see. Predators literally
look straight through them. Fish, too,
are difficult to spot in the water. Dark
bodies hide them from predators
above and silver bellies and sil-
very sides blend in with bright light
from the surface when viewed from
below. Flat fish, such as skates,

Credit: David J. Paul, Getty

Venus Wildlife Films/Oxford Scientific Films



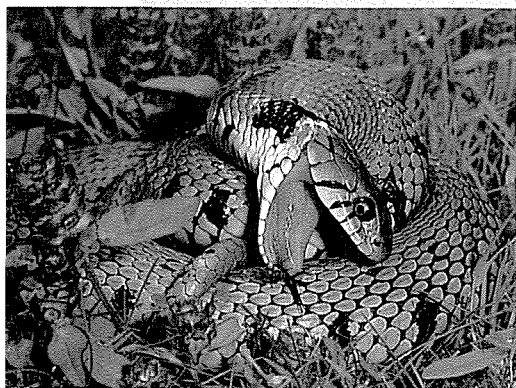
Tiger Camouflage



Simon Critchley

The tiger's stripes run vertically up and down its body, so that it merges into the jungle when stalking prey. Horizontal stripes would make the tiger stand out.

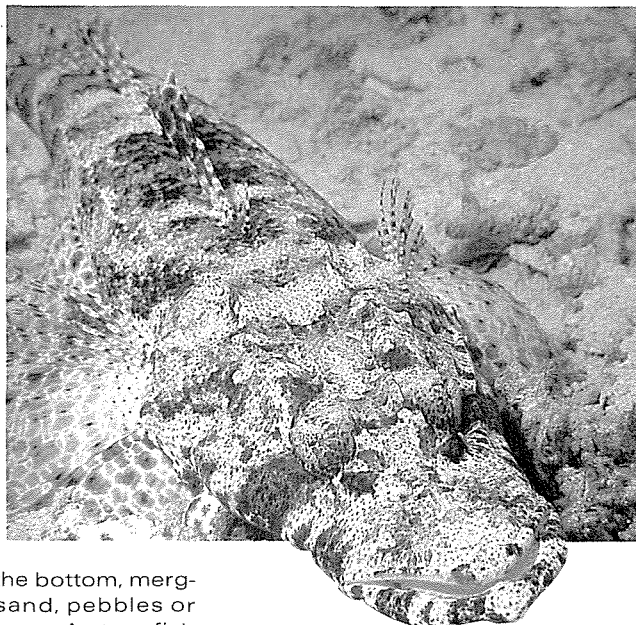
PLAYING DEAD



Jane Burton/Bruce Coleman Ltd

When in a life-threatening situation, certain species may feign death by suddenly going limp and rolling over with tongue hanging out. This appears to be an instinctive, nervous reaction. It is probably not always effective, as there are many predators that happily eat carrion. Mammals known to 'play possum' in this way include opossums, foxes and African ground squirrels. Several kinds of snake also 'play dead', including the European grass snake (above) and most American hog-nosed snakes. If picked up and turned over, a hog-nosed snake rapidly flips over again, apparently under the impression that this is the most convincing position for a dead snake.

A crocodile fish, camouflaged against the floor of the Red Sea, lies in wait for prey fish to swim by. If trodden on by a human being, its poisonous spines inflict a painful wound.



Dr George Gonnac/Science Photo Library

and plaice, hide on the bottom, merging with the mud, sand, pebbles or rock on which they rest. A stonefish looks exactly like a stone.

Land animals may have colourings that make them less easy to spot while they are still. This is particularly important for very young animals: a young fawn, for example, is well camouflaged as long as it lies motionless in the grass. The stripes of a zebra break up its outline and blend with patterns of light and shade. They also make individuals difficult to pick out from the herd.

Almost undetectable

Many birds use camouflage to avoid being caught. Nesting birds are particularly vulnerable and for this reason females are often less brightly coloured than the males. Ground-nesting birds, such as partridges and pheasants, have a mottled appearance that makes them almost undetectable if they keep still. The ptarmigan and willow grouse have white plumage in winter. An alarmed bittern sits with neck outstretched and sways from side to side. This makes it nearly impossible to see among the reeds in which it nests.

Insect subterfuge

Camouflage is also a common form of defence among insects. Beetles, caterpillars and moths usually have green or brown colorations that enable them to rest on trees and other plants without being easily seen. Patterns on the wings of some moths are arranged in such a way that they match the pattern of tree bark or lichen in the background.

Predatory insects also use camouflage. A praying mantis, coloured green or mottled brown, sits motionless on a leaf or twig waiting for a prey animal to come within reach. A few mantises are brightly coloured, resembling tropical flowers. Such 'flowers' appear uninteresting to predators and harmless to potential prey. Crab spiders use similar camouflage colours: brightly coloured

spiders sit inside flowers, lying in wait for visiting insects.

It is often difficult to pick out amphibians and reptiles from their surroundings. A brown toad, for instance, is hard to see against the ground. The long-nosed tree snake, coloured green, can easily be mistaken for a stem or vine tendril, as it lies in wait for prey.

Many animals avoid being eaten by pretending to be something that they are not. They mimic, or copy, the forms of other natural objects so realistically that they are completely overlooked by predators.

Just amazing!

WALKING BOMBS

IN A FIGHT, A MALAYSIAN CARPENTER WORKER ANT WILL COMMIT SUICIDE TO WIN. BY RUPTURING ITS OWN BODY WALL, IT SPRAYS POISON FROM SPECIAL GLANDS OVER ITS ENEMY.



Paul Raymond



Insects are particularly good at this. Stick insects resemble twigs or pieces of grass and there are several kinds of caterpillar that rest on branches in such a way as to look exactly like short twigs. A number of insects are disguised as dead or liv-

thinking them inedible. Birds tend to avoid non-poisonous hoverflies simply because they have black and yellow markings. The red, black and yellow markings of deadly poisonous coral snakes are mimicked by non-poisonous milk snakes and

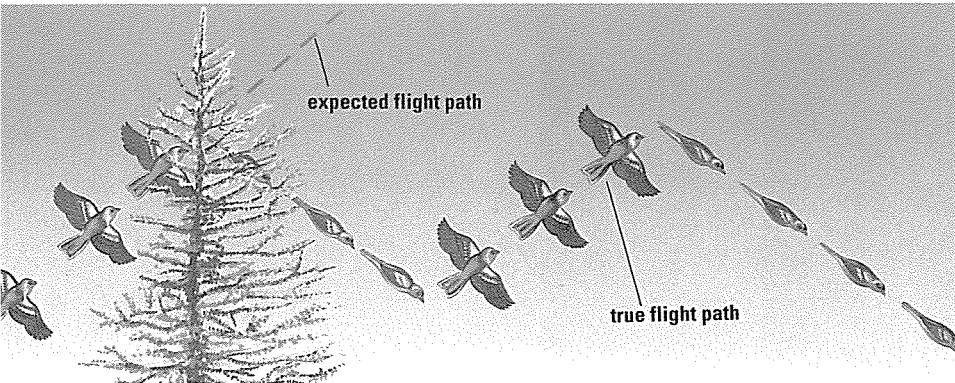
kingsnakes, so that it is difficult for predators to tell them apart.



Eye-spots

When in danger, some animals may try to bluff their way out of trouble. Several kinds of butterfly and moth have wing patterns that look like staring eyes. If a predator approaches, the insect will suddenly expose its eye-spots – making the startled predator think that it is face to face with a large animal. Before it can recover, the butterfly or moth has escaped. There is a large species of South

DECEPTION TACTICS OF THE CHAFFINCH

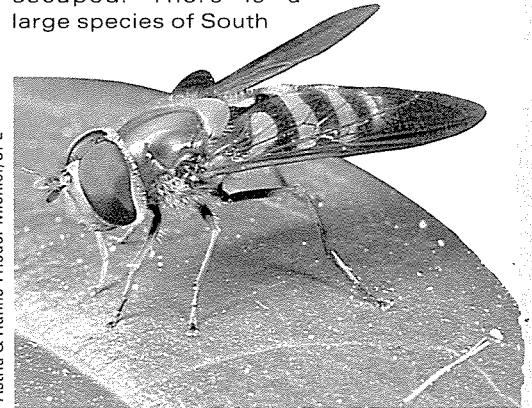


Simon Critchley

The chaffinch has a flight pattern that makes it difficult for a predator (often a hawk) to predict where it will next be. Flying up into the air, the bird flashes easily seen white patches on its wings and tail. Suddenly it dives, with wings closed and white flashes concealed. To an observer following the line of flight,

the bird seems to have disappeared. When the bird changes its direction behind a tree, this strategy is particularly effective. After diving, the chaffinch climbs again, opening out its wings and displaying its white flashes – but at a quite different point in the sky to where a predator might have expected.

Astrid & Hanns-Frieder Michler/SPL



The harmless hoverfly has similar markings to a wasp or bee, so predators (such as birds and toads) tend to avoid it.

ing leaves, often complete with blemishes and 'chewed' edges. Tree hoppers, for instance, resemble thorns. When curled up, some caterpillars look just like bird droppings, so that birds in search of a meal will naturally leave them alone.



Warning colours

Poisonous animals often have bright colours, warning predators to avoid them. A wasp's black and yellow colours are a typical example. Warning colours have been copied by many harmless animals, so that predators should be fooled into



M P Kahl/Bruce Coleman Ltd

Two heads are better than one for the shingleback lizard from Australia.

Predators are posed the problem: which head is the real one and which is actually the tail?

A luminous lure dangles just in front of the mouth of the deep-sea angler fish, looking like a morsel of food. Any small fish that is tricked into coming too close as it investigates the bait is quickly snapped up.

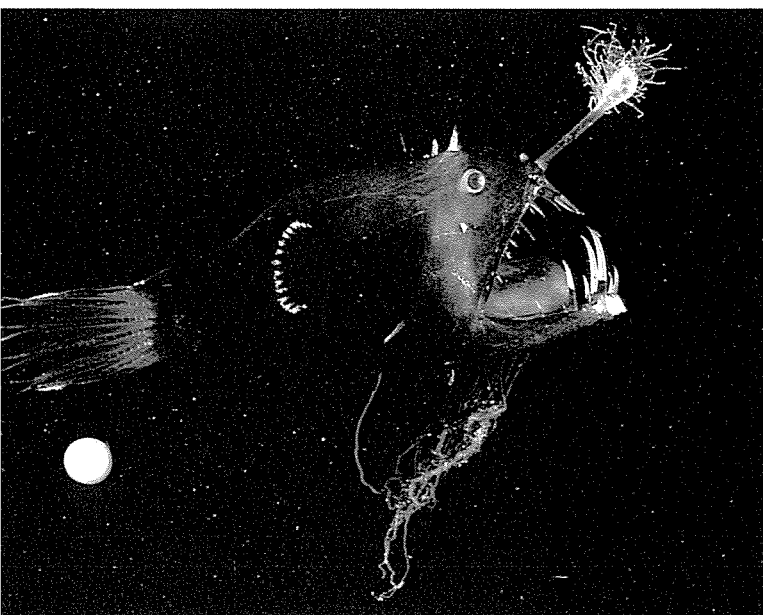
American frog that, when threatened, displays a pair of huge eye-spots on its rump.



False heads

Some species of butterfly give the impression of having a head (complete with compound eyes and antennae) at the tip of their hindwings when the wings are closed. A predator launches an attack at what it thinks is the head of the insect, only to discover its mistake when the butterfly flies off.

A number of caterpillars, too, have false eyes. Many hawk moth caterpillars can change the shape of their front end, creating a large false head just behind the (smaller) real one. When threatened, the caterpillar thrashes the false head from side to side. This gives a predator the impression that it is attacking a snake and may well frighten it away.



Peter David/Planet Earth Pictures





VIEW

PLANT POWER

A mosquito larva (called a wriggler) is digested by a bladderwort. The larva is trapped in one of the plant's hollow 'bladders' by a trapdoor that snaps shut on its victim.

Hair on a stinging nettle leaf magnified 200 times. When skin brushes against such a hair, the tip breaks off and injects the skin with toxic substances.

G. I. Bernard/Oxford Scientific Films



The rose protects itself with thorns (this one magnified 114 times) that project from the plant's stems. Each thorn is actually an adapted hair.

R. B. Taylor/Science Photo Library

The bull's horn acacia of Central America feeds ants with nectar secreted from the base of its leaves and also provides nesting places for them, inside long thorns. In return, the ants protect the tree by driving away other insects, removing fungi from leaves and destroying other plants that grow too close.



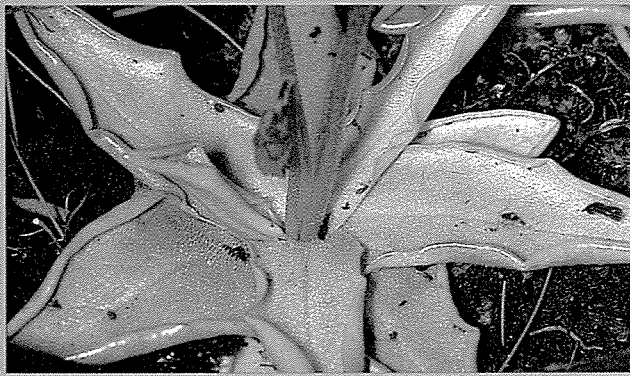
Dr. Jeremy Burgess/Science Photo Library

Insects stuck on the sticky leaves of a butterwort are absorbed by the plant as their bodies disintegrate under the action of digestive enzymes.

Wayne Harris/Planet Earth Pictures

The foxglove may look beautiful, but it contains a drug, digitalis, that is poisonous if too much is eaten.

J. LaMason/Ardea London



Philip Sharpe/Oxford Scientific Films

Deadly stinging nettle *Urtica ferox*, found in New Zealand, has killed children – and even horses – who have fallen into clumps of the plant.

Jane Burton/Bruce Coleman Ltd.



Dr. Chris Lovell



Q DOLPHINARIUMS

Q SALT EROSION

Q WATER FILTERS

OCEAN WORLDS



© 1988 The Walt Disney Company
THE WONDER OF WITNESSING sea creatures in their 'natural' environments thrills thousands of visitors to oceanaria each year. The planning and work involved behind the scenes of these ocean worlds is almost as impressive.

Brookfield Zoo in Chicago had many problems to overcome when building its new Seven Seas Dolphinarium – not least of which was recreating a salt water environment thousands of kilometres inland.



Water of life

When seawater cannot be pumped into an oceanarium, it has to be prepared from fresh water mixed with the same balance of salts and minerals normally found in the ocean.

Land and sea creatures confront each other at 'The Living Seas' exhibit at Walt Disney's EPCOT Centre in Florida – the world's largest oceanarium.

Studies of emperor penguins in captivity show that they distinguish each other by slight variations in the timing, tone and pitch of their calls. Each bird's call has been found to be unique.



CRAB MIGRATION

At the National Museum of Natural History in Washington, scientists have set up a mini ecosystem based on nearby Chesapeake Bay. The ecosystem is 15 metres long and consists of eight interconnected tanks. At one end, a trickle of fresh water represents water entering the Bay from the Susquehanna River. This feeds downstream into various tanks containing samples from appropriate parts of the real bay together with progressively saltier water. Computers control light levels to simulate night and day and to trigger the ebb and flow of miniature tides. Pre-programmed seasonal variations of daylight are proving so accurate that the population of blue crabs in the model bay migrate just as they would in the real Chesapeake.

About three-quarters of the dissolved chemicals in seawater is ordinary salt, or sodium chloride. Other minerals, such as sodium iodide and potassium chloride, are vital to the well-being of marine life.

Design considerations

At Brookfield, the dolphinarium is enclosed because of harsh Chicago winters. The building is designed to withstand the eroding effects of the salty atmosphere. Salt destroys metal and so metal supports for the structural concrete were coated with epoxy resin. Concrete was mixed with a salt-resistant additive normally used in concrete for road building.

The well-being of the animals is of chief importance and their surroundings are constantly monitored. Water is tested for pH, salt content, oxygen

Individual dietary attention ensures the well-being of dolphins at Brookfield Zoo, Chicago.

Their performing pool (above) is 7.6 metres deep and holds over 3 million litres of salt water.

The ceiling is designed to take account of the fact that dolphins can jump six metres above the water.

content, chlorine, ammonia, bacteria, temperature and hardness, and is adjusted accordingly. A chemistry laboratory is required to cope with this work. In caring for dolphins a kitchen area is also needed in which to prepare fish. And holding pools – away from the performing pool – where dolphins can rest or be quarantined when sick.

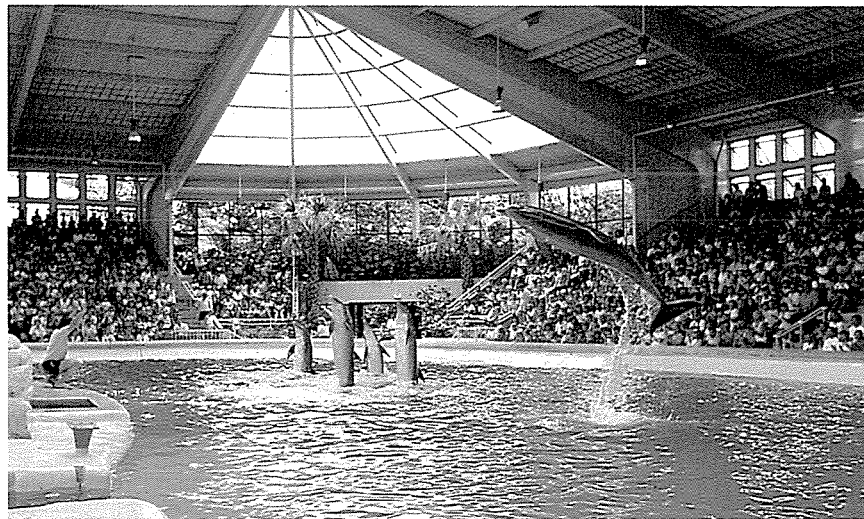
Cleaning oceanaria is more complicated than cleaning swimming pools. Swimming pools can be 'shock chlorinated' to kill bacteria and algae. The same treatment in oceanaria would harm sea creatures.

Waste disposal

Water is kept clean by continuous filtering through sand and gravel filters. Controlled chlorination acts as a disinfectant. The water is also treated with ozone to deal with organic waste that is too small to be filtered. This last process is important considering one dolphin can produce about 10 kg of organic waste each day.

Adult killer whales are the largest sea mammals in captivity. They are,

Computers control filtering systems and water temperatures at oceanaria, but elbow grease still works best to remove algae from viewing windows.



H Greenblatt/Brookfield Zoo, Chicago



like dolphins, highly intelligent creatures that can learn to perform elaborate stunts. After initial training with a target on a pole, the animals learn to respond to a variety of hand signals and whistle sounds. Dolphins, whales and seals can be taught to leap, balance objects, give rides to human trainers and make a wide range of vocalizations.

H Greenblatt/Brookfield Zoo, Chicago

Just amazing!

SHARP SHARKS

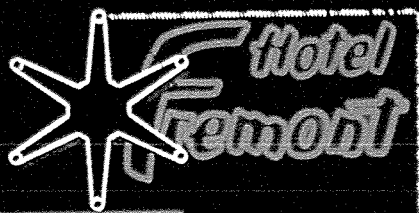
SHARKS CAN SCENT BLOOD IN WATER OVER 0.5 KM AWAY, THEIR EYES ARE TEN TIMES MORE SENSITIVE THAN A MAN'S, AND THEY CAN EVEN HEAR FISH SWIMMING.



Paul Raymond



THE NUMBERS GAME



Del Webb's

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MINT

The casinos of Las Vegas are paid for by the small advantage the house has built into games of chance. In the US, casinos use a roulette wheel (below) with a zero and a double zero, ensuring a profit of 5.26 per cent in the long run. European roulette wheels have only a zero, giving casinos a built in advantage of just 2.7 per cent.

Spectrum Colour Library

THROW A DICE, DEAL A CARD from a well shuffled pack, spin a roulette wheel - these are all ways of throwing up a completely random number. Yet though the results are quite unpredictable, they are still ruled by the laws of chance.

The chances of throwing a two, for example, when you roll a dice are one in six. This just means that in a very large number of throws, approximately one sixth will be twos. A dice can show six different numbers, and if it is thrown fairly, it will come up with each about the same number of times in the long run.

Chances and odds

We also say the odds are 'five to one' against throwing a two, meaning that in the long run other numbers will occur five times as often as a two.

If you bet on rolling a two at odds of five to one, you will get winnings of

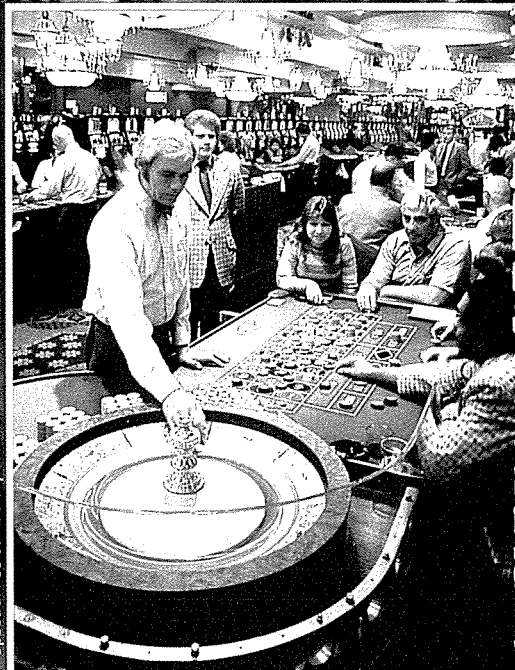
five times your stake if your two comes up (plus your stake back). In the long run your winnings will probably balance your losses.

But with organized gambling - in a casino or at a horse track - you can confidently expect to be out of pocket in the long run. What you pay in stakes and entry charges, if any, minus your winnings, has to cover the organizers' costs, staff salaries, overheads and profits.

Fair odds

In some cases, the law requires that winnings be paid out at fair odds, and the organizers' income comes only from the gamblers' entry charges. But usually their income comes from paying out at odds that are slightly loaded against the gambler.

For example, in roulette you bet on whether a particular number or combination of numbers comes up. The numbers in the game run from 1 to



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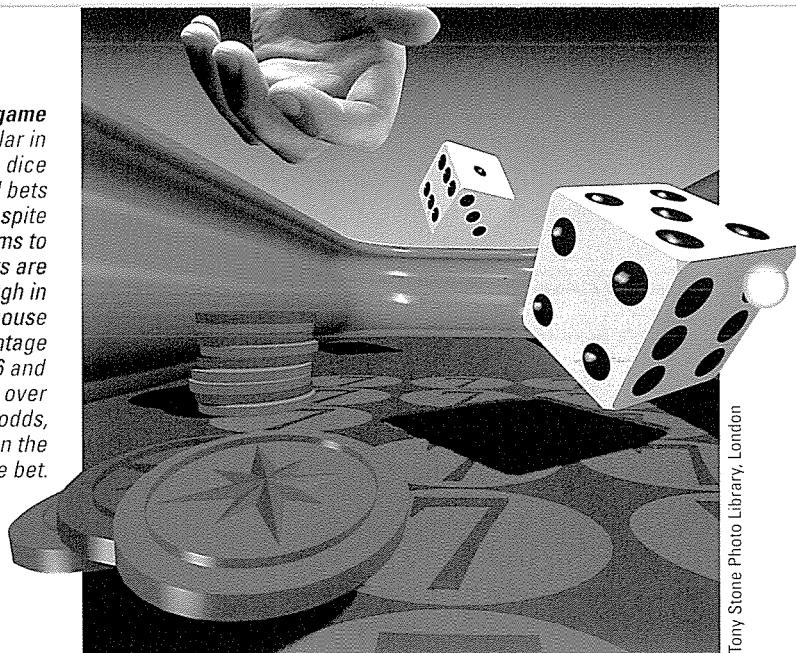


36, together with zero and sometimes double zero. Assuming there is a double zero, then a bet on a single number will win on average one time in 38. You can expect to come out at level over a long period if you are paid at the rate of 37 to one. In fact, bets are paid off at 35 to one – as if there were only 36 numbers altogether.

Beating the house

The world's casinos and race tracks are filled with people convinced they can beat the odds with some 'system'. The simplest is called the *martingale* and can be applied in any sort of gambling. All the gambler has to do is, after any loss, stake a sufficient amount to ensure that a win next time will pay off the losses so far and provide some profit. If there is a run of losses, the gambler must sit tight and

The dice game
Craps is popular in the US. Two dice are rolled and bets are placed. Despite players' claims to skill, the results are random, though in a casino, the house takes an advantage of between 0.6 and 27 per cent over fair odds, depending on the size of the bet.



Tony Stone Photo Library, London

would bet that the next number will be odd. In fact, if the wheel is fair, the chance of an odd number coming up is still the same. The chance of any number coming up – even or odd – is not influenced by the numbers that have come up before it.

Element of skill

Some games combine an element of skill with the element of chance. Poker is one of these. In the long run the good and bad luck that comes from the deal of the cards averages out and the player's skill asserts itself. Some poker players are able to make a living, financed by less skilful players.

In horse racing too, there is a tiny minority of professional punters who make a living at it. One even devised a mathematical system which indicated the horses' chances of winning. After making millions with this system, he went on to publish form books – giving others the benefit of his expertise.

In racing, the outcome is not just a matter of chance – it depends on the jockey and the horse. The odds are fixed by the money bet.

SETTING THE ODDS

In games of pure chance like roulette, the odds are fixed by the mathematics of the situation. But in less clear-cut events like horse racing, odds have to be arrived at by a longer process. Bookmakers hire experts who assess each horse's form and come up with an initial list of odds. As money is placed on each horse, the odds are adjusted accordingly. Large bookmakers will take bets on almost anything. One offers:

- 500 to 1 against the British government recognising the existence of flying saucers
- 10,000 to 1 against President Bush announcing that he has met an alien from another planet
- 500 to 1 against Elvis Presley being proved to be still alive
- 100 to 1 against London's Natural History Museum recognizing a previously unknown creature as responsible for the Loch Ness monster sightings. In 1983, the odds briefly fell to 25 to 1 following new evidence for 'Nessie'.

Jon Nicholson/Allsport



bet more and more until he wins – which must happen sooner or later.

This system fails because there is often a limit to the stakes you are allowed to bet, or if there is not, the gambler runs out of money. On a losing streak he will not be able to stake enough to provide winnings to pay off the losses already accumulated.

Many gamblers are taken in by what is known as the *Monte Carlo fallacy*. If, say, an even number comes up ten times in a row at roulette, they

Just amazing!
BIGTIME LOSER
IN 1984, WILLIAM BERGSTROM WALKED INTO THE HORSESHOE CASINO IN LAS VEGAS AND BET \$1 MILLION (AROUND £625,000) ON A SINGLE THROW OF THE DICE. HE LOST.



Paul Raymond



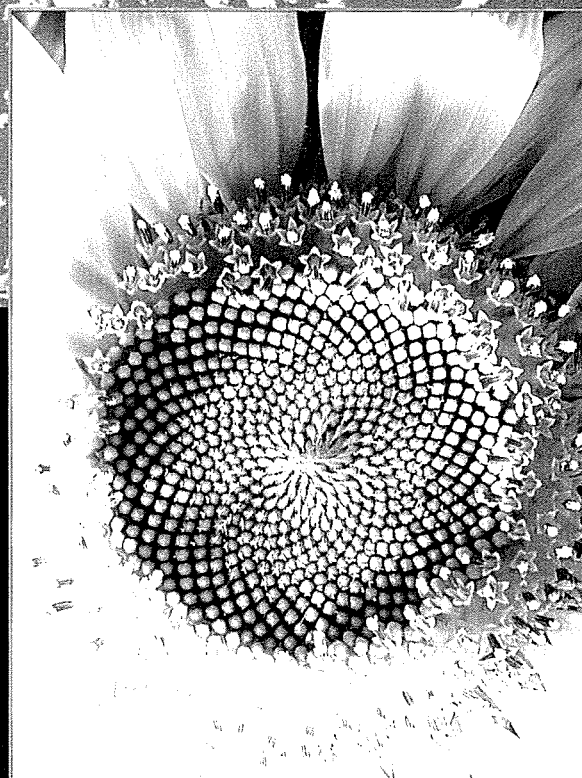
SPIRALS

MANY STRUCTURES AND patterns recur again and again in the natural world. Very often, their size and shape have not developed at random, but have built up according to strict mathematical rules.

Spirals are found everywhere - in shells, in sunflowers, in pine cones and even in galaxies, such as our own Milky Way. The most common type of spiral traces the path of a point as it rotates around a central point or line, the point gradually moving outwards from the centre. This is called an equi-angular spiral, because a line drawn from the centre will cross each coil at the same angle. It is also known as the Golden Spiral.

The shell of the pearly nautilus (a

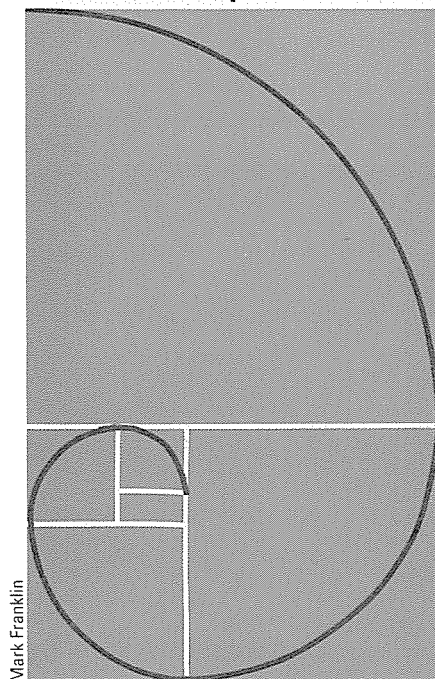
NOAA/Science Photo Library



A storm twists in a spiral over the Bering Sea in the far north of the Pacific. On quite a different scale, florets spiral outwards (above) from the centre of the head of a sunflower.



The Golden Spiral



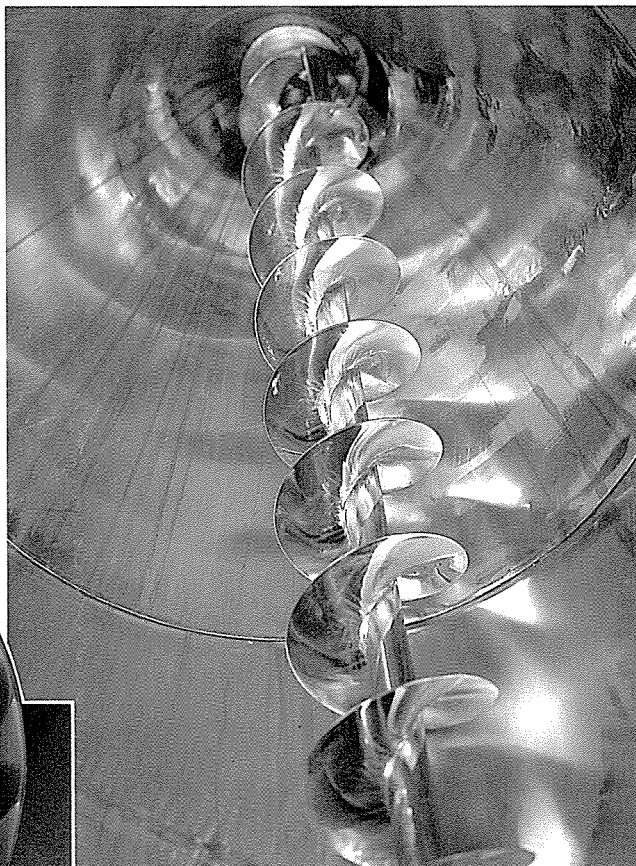
mollusc found in tropical regions of the Pacific Ocean) is a spiral of this type. It consists of a series of chambers, each of which housed the nautilus's soft body until the animal grew too large and it made another chamber for itself.

In the 13th century, an Italian mathematician called Fibonacci studied a series of numbers now named after

two-fifths of a turn round the main stem; in poplar and rose, every three-eighths of a turn; in willow and almond at every five-thirteenths of a turn – the numbers appearing in these fractions all coming from the series. The Fibonacci series cannot be explained, only observed.

When examining how many things, both living and inanimate, are

A Golden Rectangle can be divided by a single line into two parts: one a square; one a smaller Golden Rectangle. To form the graceful curve known as the Golden Spiral. Golden Rectangles are nested inside one another and a curved line drawn as in the diagram.



A screw is a wedge cut into the form of a helix – a spiral shaped like a coiled spring. The helix is the most common shape in the natural world, present as the DNA in every living cell.

ZEFA **The equi-angular spiral, or Golden Spiral, is found in the natural world in many forms, including the shell of the pearly nautilus (a type of mollusc).**

PERFECT HARMONY

The power of numbers is present everywhere – even, surprisingly, in the creation of music. Suppose a guitarist plays several notes successively on a single string. First he plays the 'open' (unfingered) string. Then he slides a finger along the fretboard to alter the length of the string that vibrates. Harmonious (sweet-sounding) notes are produced when the string is four-fifths or three-quarters or two-thirds as long as its full length (and at certain other positions). The same ratios apply to lengths of organ pipes, or the different lengths of the air paths created by pressing the keys of a valve trumpet.

him. The series begins: 1, 1, 2, 3, 5, 8, 13, 21, 34 and continues into infinity. Each number (after the first two) is the sum of the two preceding numbers. The individual numbers in the Fibonacci series occur in nature in many different forms.

Twists and turns

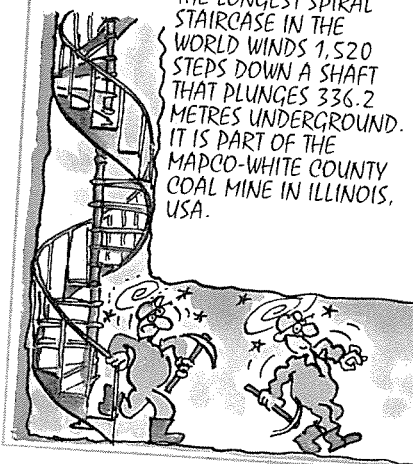
On a sunflower head, for example, you will see spirals, some turning clockwise and some anti-clockwise. (The spirals are made up of hundreds of tiny flowers called florets.) Typically, there may be 21 spirals turning in one direction and 34 in the other – two successive numbers in the Fibonacci series. The numbers of left and right-handed spirals in a fir cone are often from the series – 8 and 13 are typical examples.

The shoots on many types of leaf stem branch off at points that form a spiral around the stem. In oak and fruit trees the shoots occur every

Just amazing!

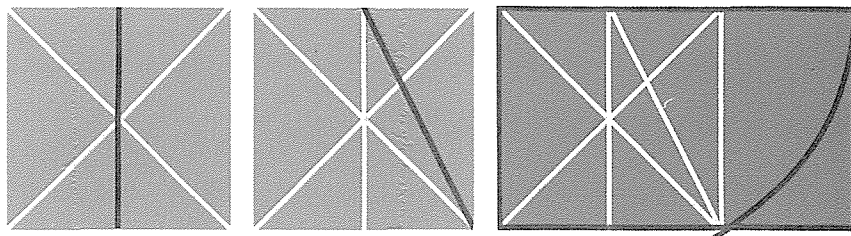
DOWN, DOWN, DOWN...

THE LONGEST SPIRAL STAIRCASE IN THE WORLD WINDS 1,520 STEPS DOWN A SHAFT THAT PLUNGES 336.2 METRES UNDERGROUND. IT IS PART OF THE MAPCO-WHITE COUNTY COAL MINE IN ILLINOIS, USA.



To construct a Golden Rectangle, divide a square into two identical rectangles (left), draw a diagonal in one rectangle (centre), then extend the short side of that rectangle to the same length as the diagonal line (right).

The Golden Rectangle



This chess piece has rotational symmetry. When rotated 90°, it looks as it did before it was moved. This can be done four times – then it is back in its original position. So the piece has fourfold rotational symmetry.

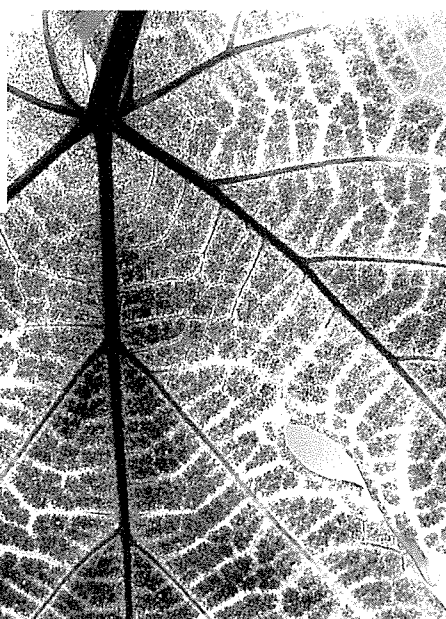
a third or a sixth of a turn, and still look the same. The shape with the highest possible symmetry is the sphere – however it is twisted, it always looks the same. The starfish is a rare example of an animal with high rotational symmetry (fivefold).

Mark Franklin

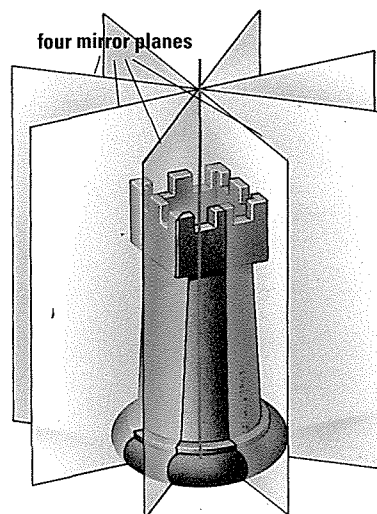
Mirror image

The head of a daisy has rotational symmetry. A butterfly, on the other hand, has reflectional symmetry. If the left half of a butterfly is reflected in a mirror, the reflection is almost identical to the right half of the insect. Many plants, orchids for example, have reflectional symmetry and so do many animals, including humans. Or rather, the human body is symmetrical externally. Our internal organs are not symmetrical – the stomach, for example, is on the left side.

Some of the most striking natural

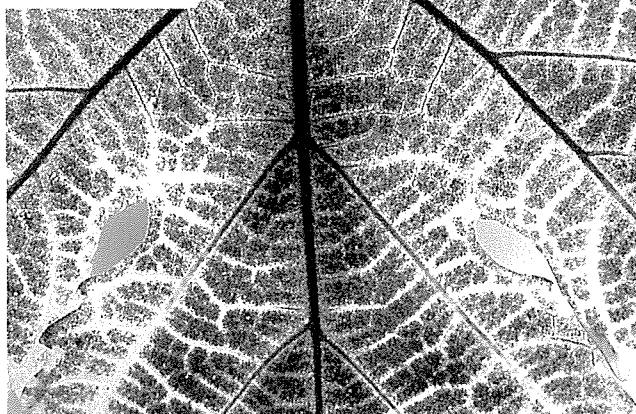


Dr Jeremy Burgess/SPL



Fourfold Rotational Symmetry

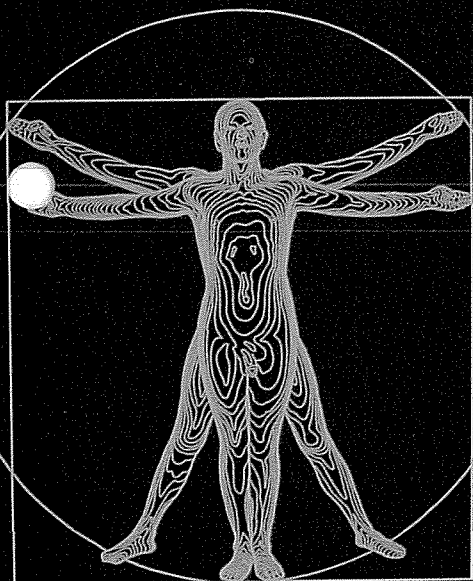
Reflectional symmetry is shown by this leaf from a grape vine. The right side of the leaf is a virtual mirror image of the left. An example in the animal world are the wings of a butterfly and in engineering, the spans of a bridge.



constructed, the importance of symmetry becomes apparent. The wings of a bird are identical, as are the two halves of a bridge span. If they were not, one half would be inferior to the other and the structure of the whole would be needlessly weakened.

To understand the idea of symme-

forms are crystals. They are classified according to their symmetries. A crystal that is a combination of a cube and an octahedron, for example, can be combined to give a form resembling a cube with its corners bevelled off. Such a shape has threefold and fourfold symmetries.

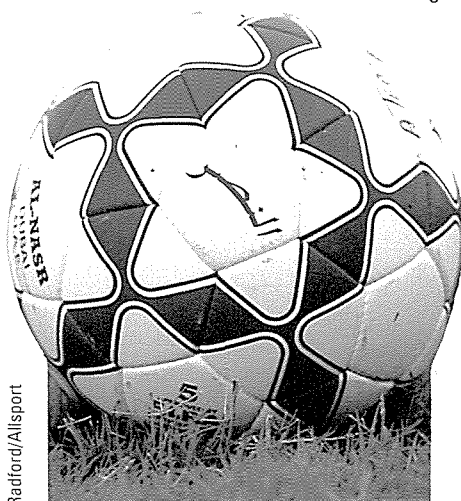


A contour map of the body from a drawing by the Italian artist Leonardo da Vinci (1452-1519), illustrating the concept that proportion is fundamental to the human form.

Dr Robin Williams/SPL

FOOTBALL ENIGMA

How can a football manufacturer make a ball from flat pieces of leather? It looks at first glance as if its surface consists of hexagons (six-sided figures). If you look closer, however, you will see that there are 20 hexagons (which, on their own can only form a flat surface) and 12 five-sided pentagons. This so-called *pentagonal dodecahedron* is a structure found in many places in the natural world. The outer coating



Ben Radford/Allsport

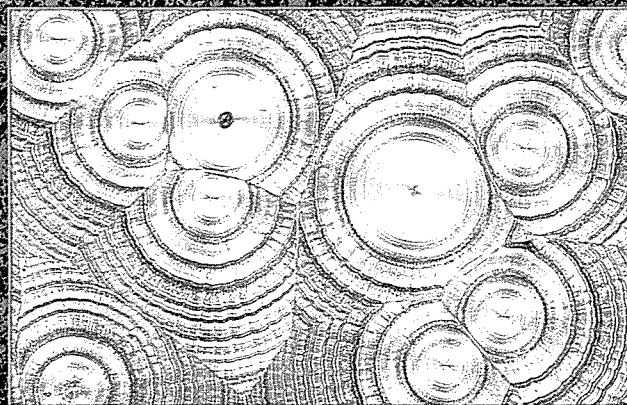
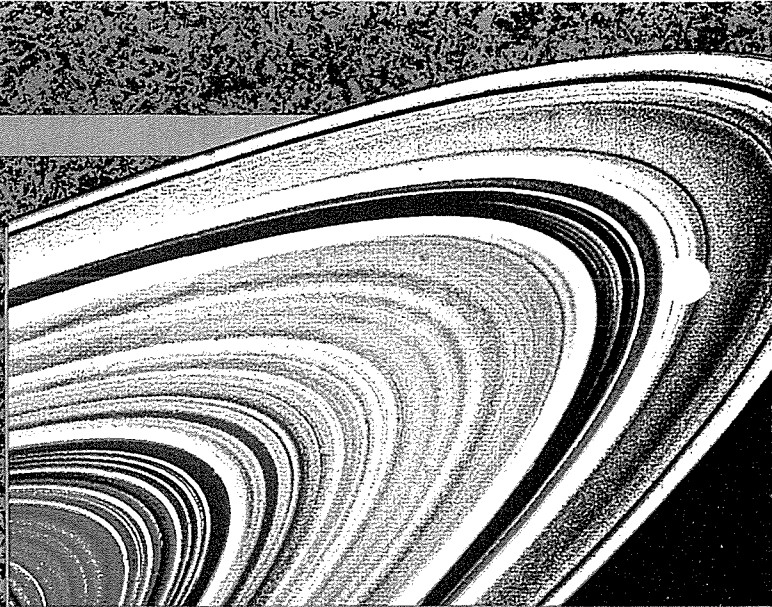
of many of the viruses that attack plants and animals are constructed around this arrangement. Similarly, a tiny single-cell life form called a radiolarion is covered with a kind of 'net bag' of hexagons and pentagons, which forms its external skeleton.





A human fingerprint showing tiny ridges on the skin. Each ridge is in a pattern unique to each human being.

The rings of Saturn photographed by US Space probe Voyager 2. The covered hundreds of rock trapped in Saturn's orbit make up the rings.

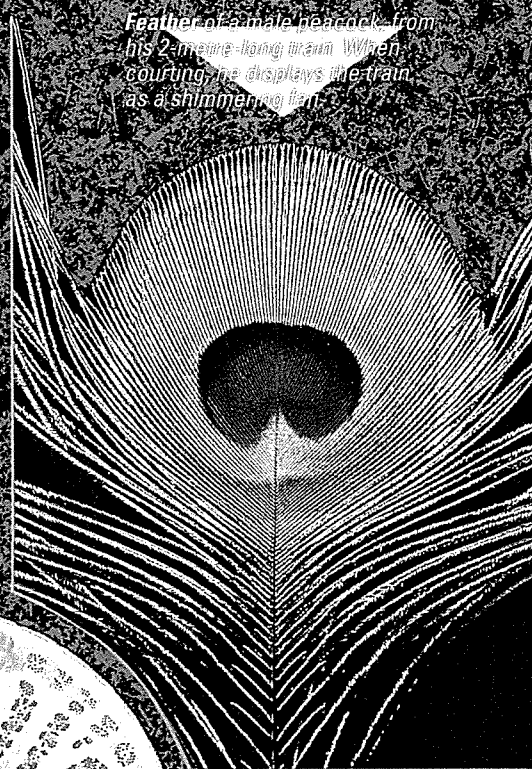


Vitamin C crystals magnified 14 times. Vitamin C, also called ascorbic acid, is found in vegetables and citrus fruits.

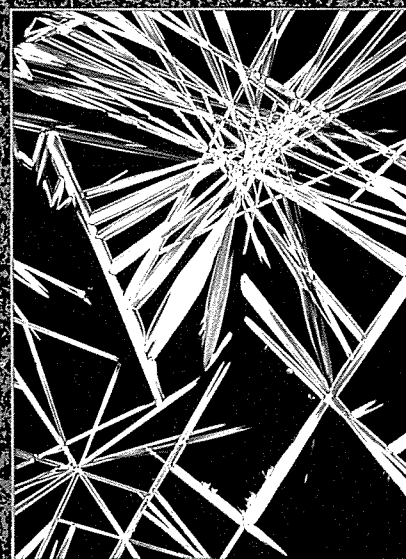
Crystals of the stimulant caffeine magnified 80 times. Caffeine is present in coffee and tea, and also in beans and some leaves.



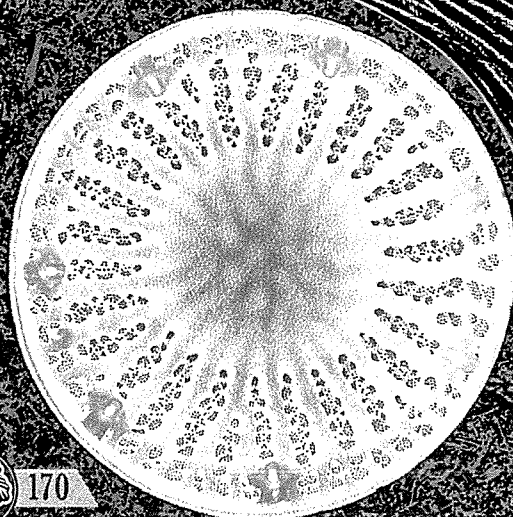
Sand ripples on a beach at low tide in Achmahand Bay, Scotland. The ripples are formed by the action of waves, as the tide comes in and then retreats, on the particles of sand that make up the beach.



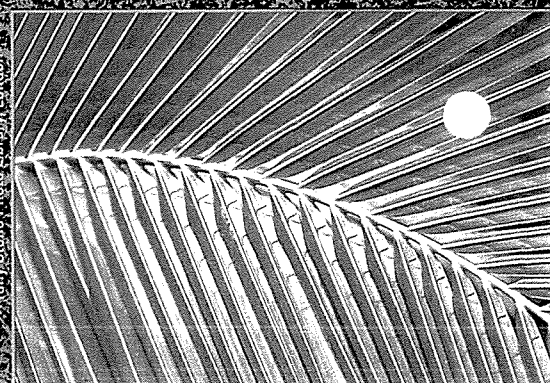
Feather of a male peacock from his 2-metre-long tail. When courting, he displays the train as a shimmering fan.



Palm leaves may grow as long as 20 metres. The leaves are clustered on tufts at the top of the plant's woody stem, or trunk, or grow at intervals along the stem.



A diatom, a type of alga found in fresh and brackish water, consists of two valves that fit together like the top and bottom of a box. This cross-section through one of the valves reveals a radial pattern of pores.



WONDER DRUGS

Protective clothing is essential when producing antibiotics (here, amoxycillin), so that a worker will not become resistant.

Crystals of the antibiotic oxycycline, purified 42 times. Oxycyclines are 'broad spectrum' drugs - effective against many types of bacteria.

MODERN MEDICINE HAS A powerful battery of drugs to fight many of the invaders that breach the body's defences. Some of the most effective drugs belong to a group called antibiotics.

Antibiotics are chemical substances produced by some bacteria

and fungi that destroy certain other types of bacteria and fungi. Penicillin, the best-known antibiotic, was discovered by the Scottish scientist Sir Alexander Fleming (1881-1955) in 1928, but did not become widely available until the 1940s. Then, its almost miraculous ability to clear up infection and bacterial diseases made it famous.

Penicillin is a complex chemical produced by the fungus *Penicillium notatum* - a mould that forms on stale bread. When it comes into contact with growing bacteria it prevents them from forming cell walls. (Only plants have cell walls; animal cells are

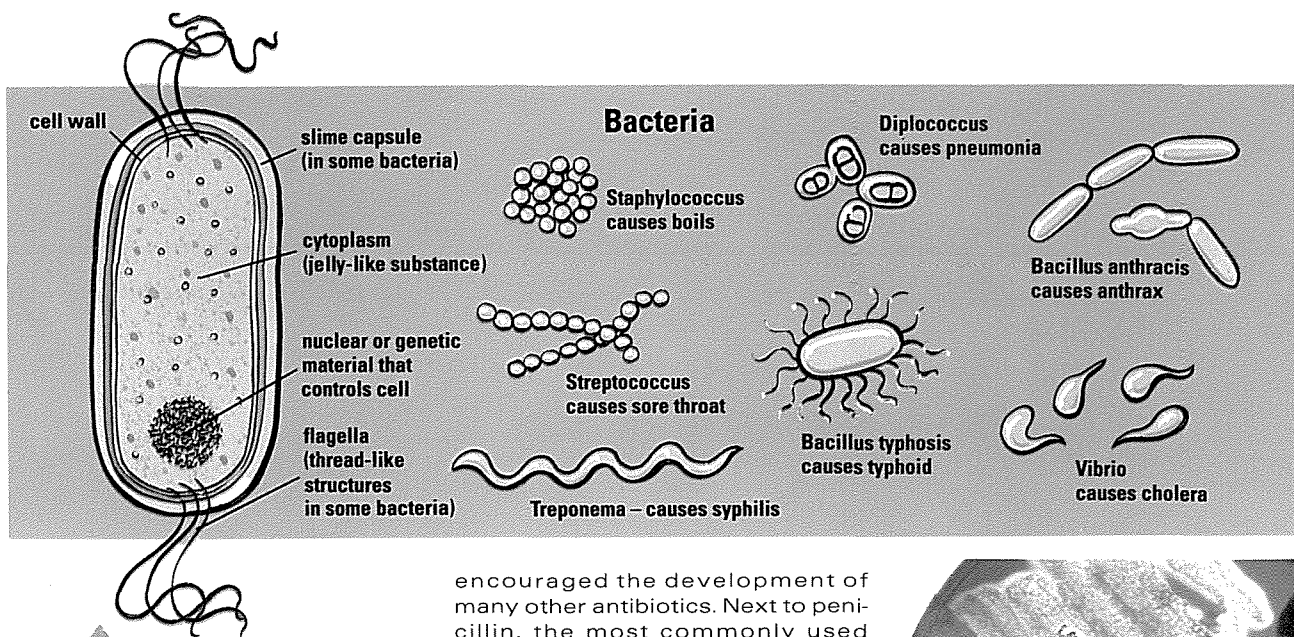
surrounded by thin membranes.) This kills the bacteria, or at least stops them from multiplying further.

Bacteria are primitive, microscopic plants that exist virtually everywhere. Millions of bacteria swarm over each square centimetre of our skin - even after a thorough wash. Billions more live permanently inside us and perform vital functions, such as producing one of the chemicals that help blood to clot.

Invading the body

Disease-causing bacteria, however, can also get into the body, entering through natural openings, such as the nose, mouth, ears and eyes, or via an untreated cut or scratch. Once inside, the bacteria break into living cells and feed on substances in them. As they





Simon Critchley

Most bacteria are found in water, soil or decaying matter; some live in the intestines of animals, including Man. A bacterium is a living organism, from 0.0005 to 0.01 mm long.

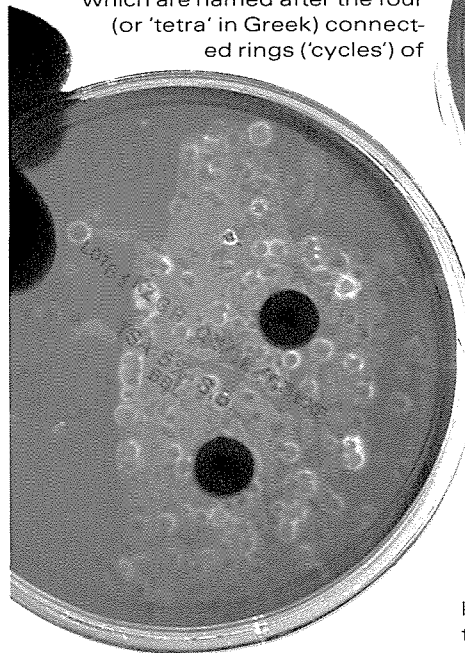
multiply, they may release toxic chemicals that cause fever, vomiting or other symptoms. The body fights back with its own defending army of white blood cells. But this may not be enough to prevent a serious or even life-threatening illness from developing. Then the only hope of a swift cure is a course of antibiotics.

The bacteria that penicillin works best against include those responsible for pneumonia, scarlet fever, meningitis and throat and skin infections. The drug's success has

SIDE EFFECTS

Many antibiotics have side-effects – that is, unavoidable and unwanted effects. A minor reaction, such as indigestion, is often tolerated; it is more important that the antibiotic tackles a bacterial infection. But if the side-effects are dangerous or an allergy is discovered, the patient is taken off the antibiotic immediately. Reactions to tetracycline, for example, can range from discoloured teeth, as shown below, through blackened finger nails to the skin reddening and blistering when exposed to sunlight.

encouraged the development of many other antibiotics. Next to penicillin, the most commonly used antibiotics today are the tetracyclines, which are named after the four (or 'tetra' in Greek) connected rings ('cycles') of



The effect of the antibiotic biactrin on two species of the *Streptococci* bacteria that cause sore throats is tested here. Two discs of biactrin in the right-hand dish have inhibited the bacteria's growth. But biactrin has little effect on the strain of bacteria in the other dish.

Van Bucher/Science Photo Library

kind of food-poisoning). 'Semi-synthetic' antibiotics, such as some of the tetracyclines, have also been developed, by adding chemicals to the growing medium.

carbon atoms in each of its molecules.

When an antibiotic is used, the whole course of treatment prescribed by the doctor must be taken, or bacteria not yet destroyed will stage a 'comeback'. Even after this, there is still the risk that some strains of the target bacteria may become resistant to the antibiotic. These surviving bacteria reproduce rapidly and when the same antibiotic is used against them later it has very little effect. Fortunately, where one antibiotic fails another may still be effective.



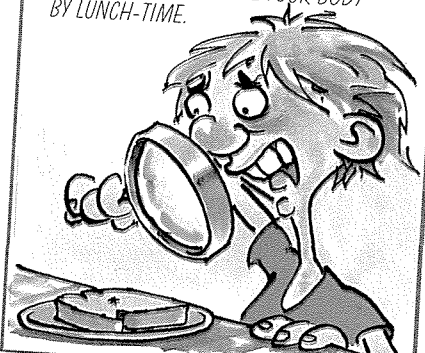
Natural and man-made

Many antibiotics, including penicillin, are made naturally by various fungi and bacteria found in soil. Such antibiotics are extracted commercially from bacteria and fungi raised on special, rich nutrients. The antibiotic streptomycin, for instance, is obtained from a certain soil mould. A related fungus has yielded a drug (chloramphenicol) that attacks the bacteria responsible for typhoid fever and salmonella (a

Just amazing!

SPECIAL ADDED EXTRA

BACTERIA MULTIPLY SO FAST THAT A SINGLE BACTERIUM ON YOUR BREAKFAST TOAST COULD BECOME AN ARMY OF 30,000 INSIDE YOUR BODY BY LUNCH-TIME.



Paul Raymond

John Radcliffe Hospital/Science Photo Library



NERVOUS CONTROL



LEVER MECHANICS



CHEMICAL CHANGES

MUSCLE

POWER

MUSCULAR TISSUES GIVE our bodies their contours. They attach to the skeleton at specific sites so that when they contract each muscle produces a slightly different movement. The complex result of many muscles contracting in unison produces the controlled precise movements that we all take for granted.

The body has 620 muscles that work to move the 206 bones of the human skeleton. A further 30 or so muscles control the movements of our gut, help us to swallow our food and pass it through the intestines, assist the internal organs and pump blood around the body.

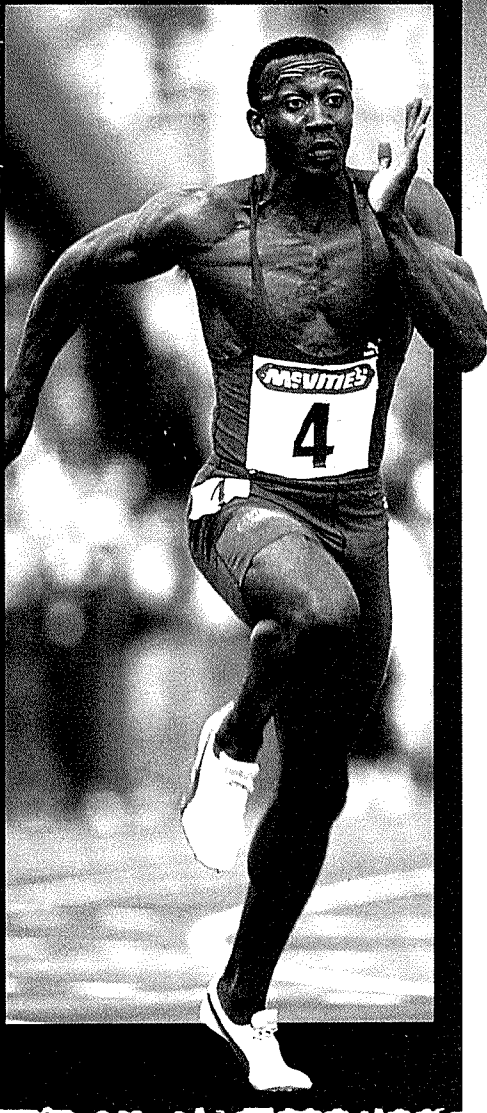


Motor nerve fibres

The muscles that we consciously control are called voluntary muscles. Voluntary muscles can be called striated or striped muscles because of their appearance under the microscope. They are also referred to as skeletal since they are attached to the bones. They are under direct conscious voluntary control from the brain. With very few exceptions (such

Sport stretches our muscular co-ordination to the limit. Constant monitoring and feedback of information takes place at a phenomenal rate – unknown in the conscious mind. To build a machine with the skills of an athlete would be very difficult.

Gray Mortimore/Allsport



Muscles make up about 43 per cent of male and 36 per cent of female body weight. Different distributions of muscle and fat equip women better to withstand extremes of environment and give them a longer life expectancy. Men have greater muscular power and speed.

Anthony Crickmay/London Contemporary Dance Theatre



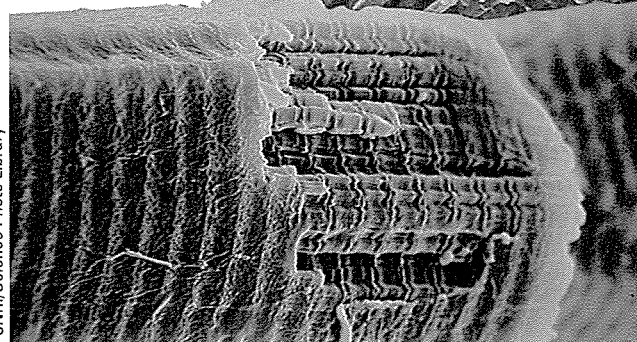
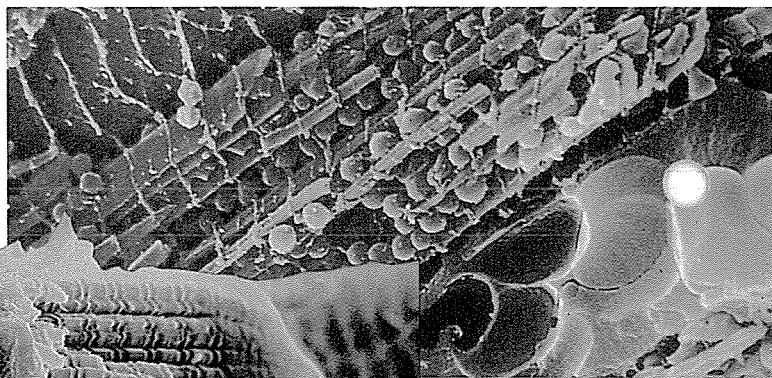
as the blinking of the eye) single muscles never contract by themselves: rather, sets of muscles contract together or in sequence.

The nervous system is the control mechanism for muscular movement. Signals are sent from the brain and spinal cord along motor nerve fibres. These cause the release of a chemical called acetyl-choline that in turn causes muscle fibres to contract.

Involuntary muscle

In yet another classification, voluntary muscles are called phasic muscles because they move limbs – as opposed to the supportive, paravertebral muscles of the back, for example, that are constantly contracting to keep the body upright. Involuntary muscles are sometimes called smooth or unstriated because of their appearance

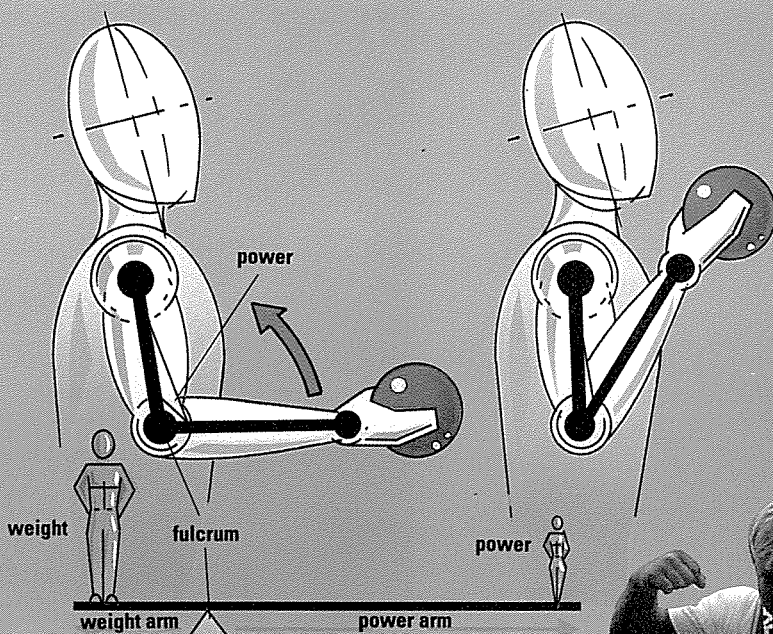
Muscle filaments, in this false colour scanning electron micrograph, are made of proteins. The mitochondria (small balls) process the energy from food materials to power muscles.



Striated muscles are divided into bands of protein filaments that slide over each other to cause contraction of 30 to 40 per cent of their length.

Manfred Kage/Science Photo Library

LAW OF LEVERAGE

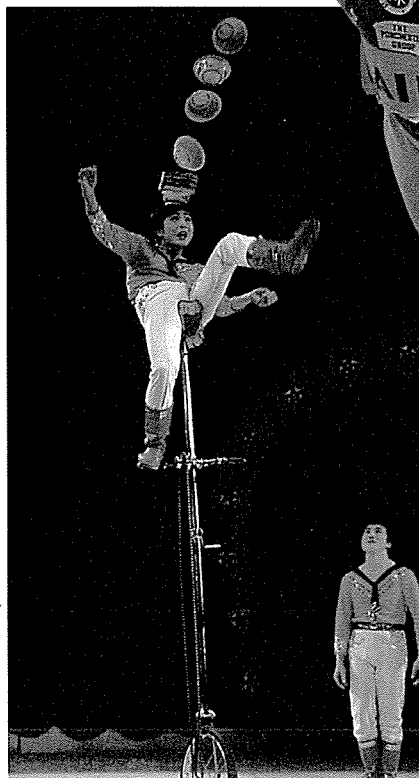


Simon Critchley

Voluntary muscles perform their many functions by pulling on bones and using joints as hinges. The mechanics of levers allow muscles to lift heavy loads by amplifying their power. Pulling the lid off a paint tin with your fingers is almost impossible. But by inserting a screwdriver under the lid and using the edge of the tin as a fulcrum a small force will pop the lid off. The see-saw diagram (above) illustrates the lever effect.

Within the body the spinal column, for example, acts as a fulcrum for the muscles at the back of the neck to pull the head back so that we can look up. The elbow acts as a fulcrum for the arm muscles. In the examples above, the law of leverage can be written: power x power arm = weight x weight arm.

The poise and balance demonstrated by gymnasts is perfected by the daily training that also builds muscular strength and suppleness.

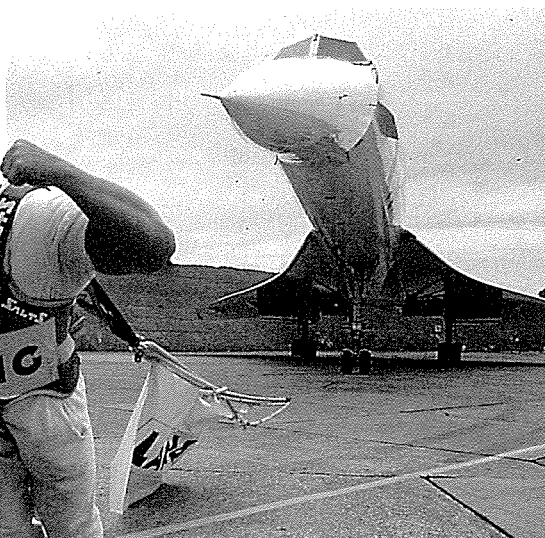


under the microscope. Their other name is visceral, since they surround the internal organs or viscera.

The heart pump

Because there are so many organs all doing different things, the brain could not voluntarily control these and the skeletal muscles at the same time. Therefore, there is a special part of the brain devoted to controlling the muscular activity of internal organs automatically so that the rest of the brain is free to concentrate on voluntary activity of the body (see

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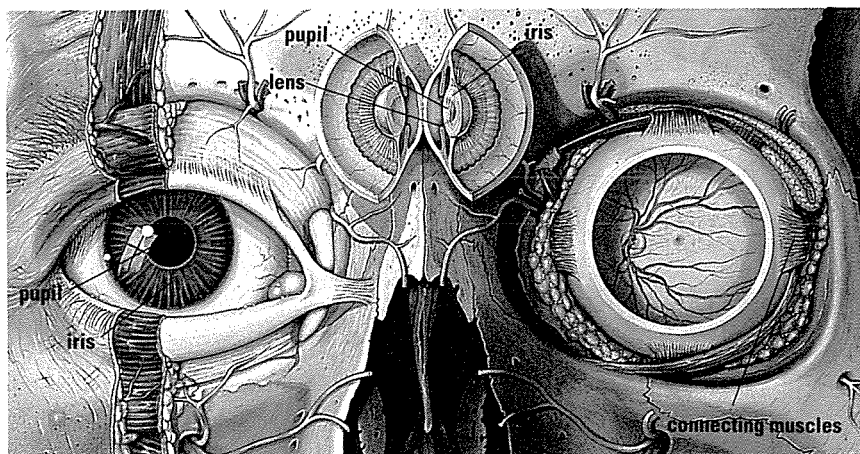


Record-breaking strongman Dave Gauder pulled Concorde's 102.6 tonnes 12.19 metres across the tarmac at Heathrow Airport, London, in 1987.

THE LIVING WORLD page 107).

The heart is a four chambered muscular pump under involuntary control. But because it is a unique type of muscle it has a classification all of its own – 'cardiac'. The biggest difference between cardiac and other types of muscle is the presence, in the heart, of a structure called an

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Peter Cull/Science Photo Library

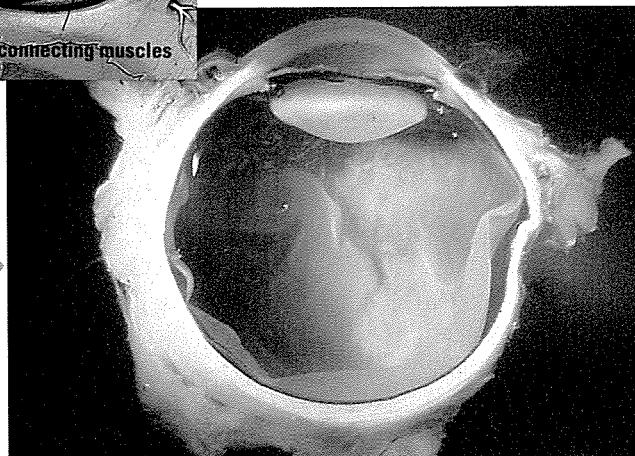
intercalated disc. This disc of tissue, found between each muscle fibre, helps transmit nerve impulses from one muscle fibre to the next, making the cardiac muscle very efficient.

Contractions

Some muscles with varied functions have developed special characteristics. The muscles that move the eyeball contract and move the eye very quickly (the eye can change its direction of gaze in 1/100th of a second). This type of muscle is termed fast-twitch or white muscle, it looks white due to the lack of a dark substance called myoglobin.

On the other hand, the muscle of, say, the calf does not need to contract at such a

The iris – above the white oval lens in this eye cross-section – is a ring of muscle that controls the amount of light entering the eye. The eyeball is held in its socket (above) and smoothly rotated by an intricate system of muscles.



Ralph Eagle/Science Photo Library

fast rate to move the leg, it is termed slow-twitch or red muscle (contracting in about 1/30th of a second). The red appearance is due to high concentrations of myoglobin and the presence of many small blood vessels called capillaries in the muscles.

All muscles have in common the

Standing still for long periods prevents the squeezing action of muscles returning blood through the veins to the heart. This in turn restricts the blood supply to the brain and causes fainting. Guardsmen on duty bend their knees and rise onto their toes to contract their calf muscles, stopping themselves from fainting.

BURNING SUGAR

Working muscles convert fresh supplies of oxygen and glucose (sugar), supplied by the blood, into mechanical work. The chemical process breaks down the glucose into carbon dioxide and water and in doing so releases the energy that muscles use to contract.

During exercise the blood cannot supply oxygen fast enough, and so muscles convert stored glucose (glycogen) into lactic acid without the help of oxygen. Thus exercise is slimming because it uses up the body's stores of sugar.

There is a limit to the intensity with which we can exercise our muscles. Beyond this movement becomes painful and then impossible. Lactic acid accumulates, tiring the muscles and causing cramps. This excess is removed by oxygen, which the body brings in rapidly by panting to pay off the oxygen debt.

Tony Stone Photo Library, London

ability to contract. The contractile mechanism is very complicated, involving a series of nervous signals and chemical changes. Every muscle fibre is made up of smaller thick and thin fibres called filaments. The thin filaments are made of a chemical called actin and the thick ones of a chemical called myosin.

The myosin filaments provide a number of cross bridges, the ends of which can be chemically attached and detached from the actin filaments. During muscle contraction the

two types of filament slide over each other – the cross bridges acting like oars on a boat 'pulling' the filaments over each other.

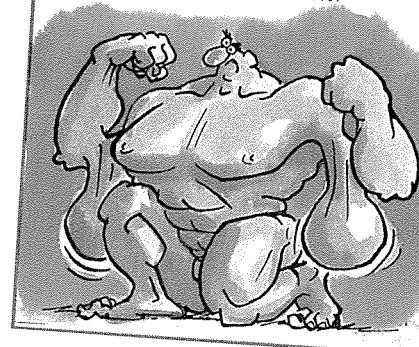
Muscle pairs

While one muscle is contracting and becoming shorter, for example the bicep – at the front of the upper arm – the muscle on the back of the upper arm – the tricep – is relaxing and lengthening. Muscles work together in pairs. One moves a part of the body in one direction and the other moves the same part of the body in the other direction. Other muscles act as stabilizers – to make movements both smooth and controlled (see THE LIVING WORLD page 106).

Just amazing!

PEA BRAIN

MUSCLES ARE THE HEAVIEST COMPONENT OF THE HUMAN BODY. FOR A MAN OF 70 KG MUSCLES MAKE UP ABOUT 43% OF BODY WEIGHT – WHILE THE BRAIN MAKES UP ONLY 2%.

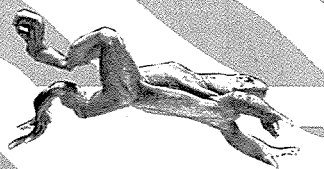


Paul Raymond



VIEW BRUTE FORCE

The explosive power of the frog's hind legs sets it apart from other amphibians. They can propel the frog twelve times its own length.



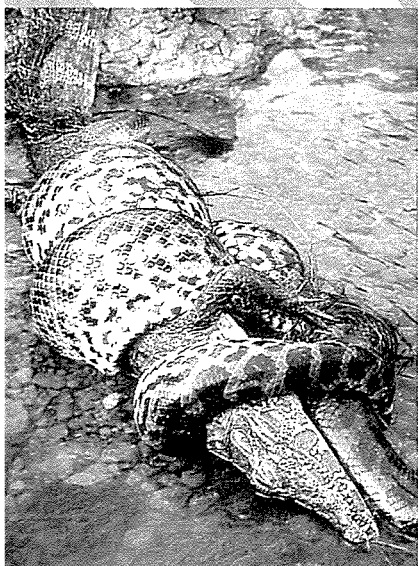
The elephant's size evolved not for strength, but to enable the species to live on great volumes of less nutritious plants than required by smaller herbivores in a competitive feeding area.

The cougar, like most cats, stalks prey. Powerful hind limbs then provide the thrust for capture with a short burst of speed. This acceleration allows cats to catch faster animals.



Stephen Dalton/NHPA

E Hanumantha Rao/NHPA



Tony Stone Photo Library, London



The anaconda's muscles are deadly. The snake, the largest of boas, kills by constriction. It winds around its victims and contracts its muscles—squeezing prey until it suffocates.

Martin Wendler/NHP

The flightless ostrich—the world's largest living bird—is built for running over the plains of its native Africa. A fully grown male stands 2.5 metres tall.

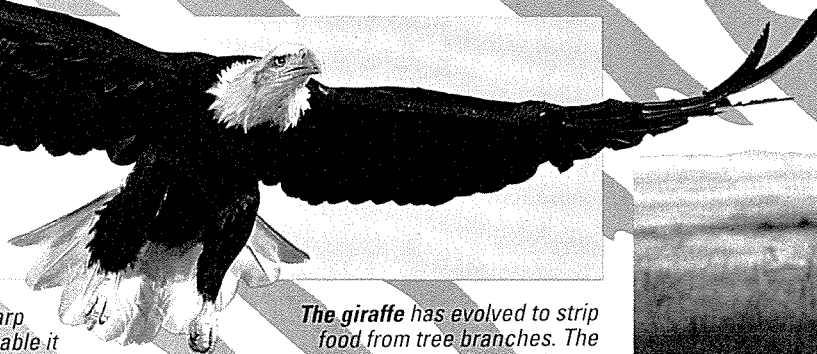
Jen & Des Bartlett/Bruce Coleman Ltd



Richard Packwood/Oxford Scientific Films

Stephen Dalton/NHPA

The powerful legs and sharp claws of the bald eagle enable it to seize and carry off live prey, such as fish, rodents and even young lambs.



The giraffe has evolved to strip food from tree branches. The result is badly designed—it puts strain on the supporting muscles of the back and the spine.



Q COCOONS

Q SILKWORMS SILK

Q SPIDERS WEBS

HOMESPUN

Spiders construct intricate webs to catch weak flying insects that cannot see fine silk. To start the construction of an orb web, the spider casts a single pilot thread to the wind until the other end is anchored.

MAN IS NOT THE ONLY animal that likes to build. Apart from smaller mammals such as the beaver, there are less sophisticated creatures that engage in construction. Insects, in particular, build for shelter, protection or to trap other animals.

These animals are small. They are more vulnerable to attack and to extreme heat or cold. For example, the larvae of butterflies, moths and caddis fly build themselves cocoons in which they pupate—that is, when they metamorphose or change from their infant to their adult form.

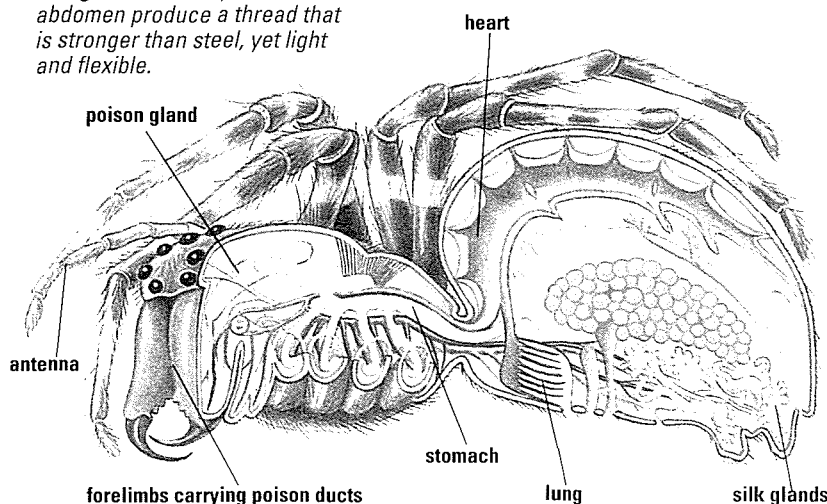
Unprotected

At this stage of their development they are unable to protect themselves by either fight or flight, so they wrap themselves up against the world. They are able to secrete silk or similar substances to spin cocoons around themselves, or to cement together grains of sand, sticks or bits of leaf to form shelters. These are extremely tough and present an impenetrable shield to the larvae's normal predators.

The most famous of the cocoon producers is the silkworm. These are

Silk glands in the spider's abdomen produce a thread that is stronger than steel, yet light and flexible.

Anatomy of a spider



raised on mulberry leaves. The silkworm's cocoon is woven from a single thread between 600 to 900 metres long. A protein called fibroin is secreted in liquid form from two glands in the worm's head. This hardens on contact with the air. A second

pair of glands produce a gummy substance called sericin that sucks the turns of the thread together.

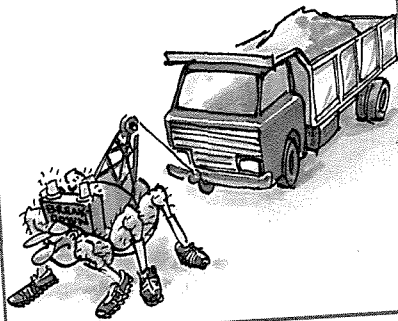
The domesticated silkworm makes a completely closed cocoon that would be broken by the emerging moth, so the larva is killed by steam or hot air.



Just amazing!

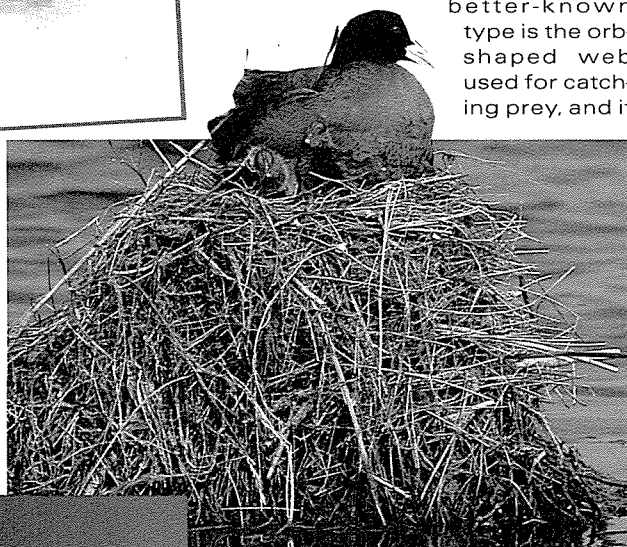
WEBS OF STEEL

THE SILK PRODUCED BY SPIDERS AND INSECTS IS STRONGER THAN THAT OF HIGH GRADE STEEL DRAWN TO THE SAME DIAMETER.



Paul Raymond

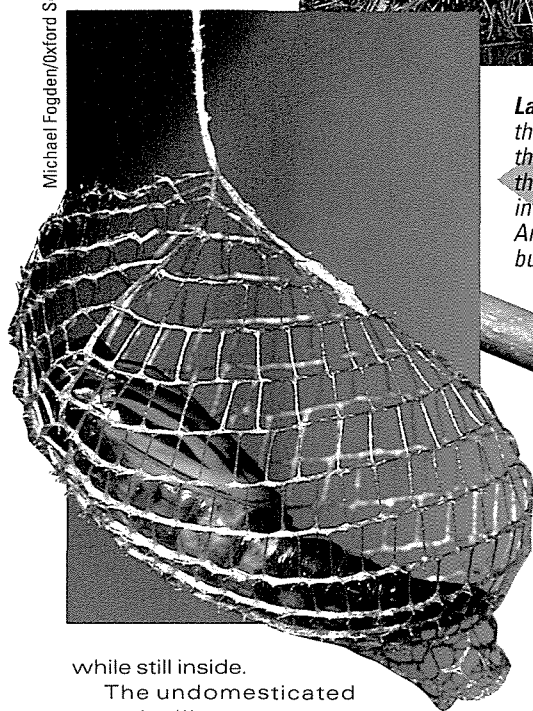
The coot protects its eggs and its young by building its nesting on vegetation in still water. Although the young quit the nest after a few days, they return to the brooding platform for up to eight weeks.



Barry Walker/Oxford Scientific Films

Larvae protect themselves while they change from the infant stage into adults. This Amazonian moth builds itself a cage.

One cupmoth caterpillar makes its cocoon next to a finished one. The caterpillar rolls itself up, while it weaves a silken cocoon around itself with a lidded roof. The caterpillar turns into a moth inside.



while still inside.

The undomesticated tussah silkworm leaves one end of the cocoon open, sealed only with sericin. This moth breaks the seals and escapes without damaging the silk filament.

Silk threads

The cocoons are collected, the binding sericin is softened and the thread is unwound. The silk filaments from several cocoons are twisted together to make a single silk thread that is thicker and strong enough to

weave fabric. Silk containing sericin is called raw silk, though this is often removed with soap and boiling water. 'Spun' silk is made with shorter lengths from broken cocoons.

Other forms of silk are produced naturally by other insects and spiders from special glands in their abdomens. They use their multi-jointed arms and mouths to work it into intricate patterns with meshes so fine that they are practically invisible to the spiders' flying prey.

Catching prey

Silk filaments are incredibly strong and light, which makes them perfect for spinning into spiders' webs. The better-known type is the orb-shaped web used for catching prey, and it

is a strange fact of nature that two separate groups of spider spin webs of identical designs, although the way they work is very different.

The *Araeidae* and *Tetragnathidae* families of spiders make webs, up to 60 cm wide, that work by having 'capture' threads covered with small sticky droplets to ensnare prey. The other group of smaller spiders, the *Uloboridae* family, produce dry capture threads, but these are covered with a fuzz of fine threads with loops and barbs to snare prey.

The bolas spider

Capturing butterflies or moths is difficult because their bodies are covered with tiny scales that are loosely attached and allow them to get free

ARTIFICIAL SILK

Man has now been able to recreate the silk from spiders' webs. The US Army's Natick research, development and engineering centre south of Boston has been studying the genetic programme used by the Golden Orb weaver spider, and has managed to reproduce spider silk in the laboratory.

Once the gene responsible for producing silk is isolated, it is transferred to bacteria that produces a soluble version of the silk protein. Then it is refined and spun into a silk-like thread. Researchers hope to adapt the process to produce super-strong fibres, which would have a wide range of uses in military materials that need to be strong and very light, such as bullet-proof clothing or parachutes.

from a web with the loss of only a few scales that soon grow back.

To overcome this problem, one bolas spider that specializes in capturing moths hangs a single thread from one leg and swings it back and forth, or throws it at the moth.

Communal webs

The strand has very large sticky droplets on it that are too much for the moth to escape from, sticking more than just a few loose scales.

The *Agelena consociata* from Gabon and the *Stegodyphus*

from Pakistan construct communal webs. Prey is killed by packs of spiders that hunt together. Other spiders build their webs at dawn then, later, eat their webs to give them the raw materials to weave more the next day.

Mantis Wildlife Films/Oxford Scientific Films



MALE BEAUTY

- PEACOCKS
- MATING DISPLAY
- DANGER SIGNALS

MANY ANIMALS AND PLANTS are extremely beautiful. But beauty usually has a purpose. It can help to attract a mate or a pollinating insect, or even warn a potential enemy of danger.

Often the males of a particular species of animal are more colourful or highly ornate than the females. In these species, the female chooses her mate from among the males, which posture or dance at the start of each breeding season. The brighter or more showy the male, the greater are his chances of being selected.

Fantastic shapes

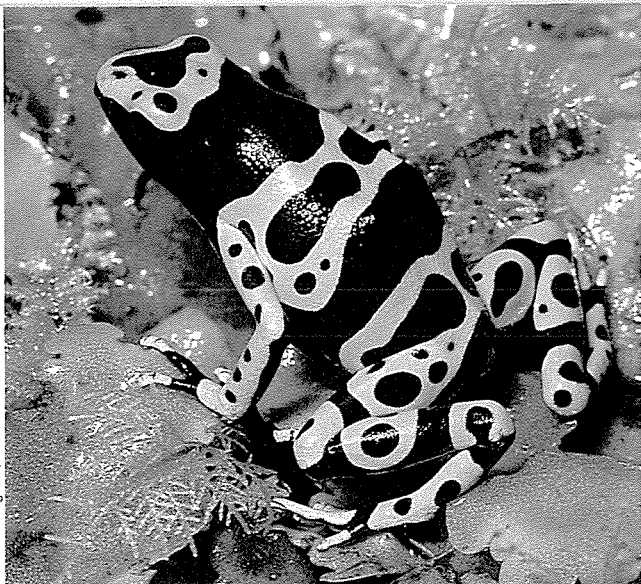
Birds of paradise earn their name from the exotic plumage of the male. While the females are a drab green and brown, the males have brightly coloured, iridescent feathers, which grow into fantastic shapes. The blue bird of paradise, for example, even hangs upside-down, quivering, to display its feathers to maximum effect.

Male peacocks resemble the females when young, but develop fabulous plumes on their upper tail coverts – the feathers that cover the real tail – as they mature. By spreading these special feathers, the male attracts as many partners as possible. After mating he leaves the females to make the nests, incubate the eggs and raise the baby birds alone.

Some birds, while lacking gor-

The male peacock impresses his mate, the drab-coloured peahen, with a magnificent display of tail feathers and colourful plumage.





The dart-poison frog, which inhabits the rainforests of Costa Rica, advertises its toxic qualities with its bright yellow and black skin. In nature, these are warning colours.

The magpie is known for its thieving. It decorates its nest with bright, often man-made, objects to attract a mate.



to attract a mate. Dominant males are able to build bigger and more spectacular collections of objects by raiding, and even destroying, the bowers of their rivals. The females are drawn to the 'wealthiest' males.

Warning signal

Often beauty, or at least gaudiness, acts as a warning signal. Otherwise defenceless creatures, such as caterpillars, use two main methods to avoid being eaten. They either try to blend in with their background so they are hard to spot, or they are purposefully showy to advertise the fact that they would not make a good meal. Brightly coloured caterpillars are generally unpleasant or actually poisonous for predators to eat.

The dart-poison frogs, which inhabit the rain forests of South America, signal an even more deadly

geous feathers, make up for this by decorating their nests in incredibly ornate ways. Magpies have a reputation for stealing shiny, man-made objects to brighten up their homes.

Blue bowers

The bowerbirds of New Guinea and Australia go to even more amazing lengths. The male bowerbird builds a special place, not as a nest, but as a mating site. Some species construct neat passageways of grass and twigs, while others erect stick palaces three metres high. Then the bowerbird starts to collect a bewildering range of coloured objects. Blue is a favourite colour – blue pieces of plastic, buttons, pen cartridge cases, bottle tops and so on. Bowerbirds have even been known to kill small blue birds and strip them of their feathers for use as decoration.

Male bowerbirds go to this trouble

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The dart-poison frogs, which inhabit the rain forests of South America, signal an even more deadly

A monarch butterfly feeds on a milkweed flower. Its bold orange and black pattern warns birds and other insect-eating animals that it is poisonous. In autumn, monarch butterflies in North America fly south in large numbers to California and Mexico where they hibernate.

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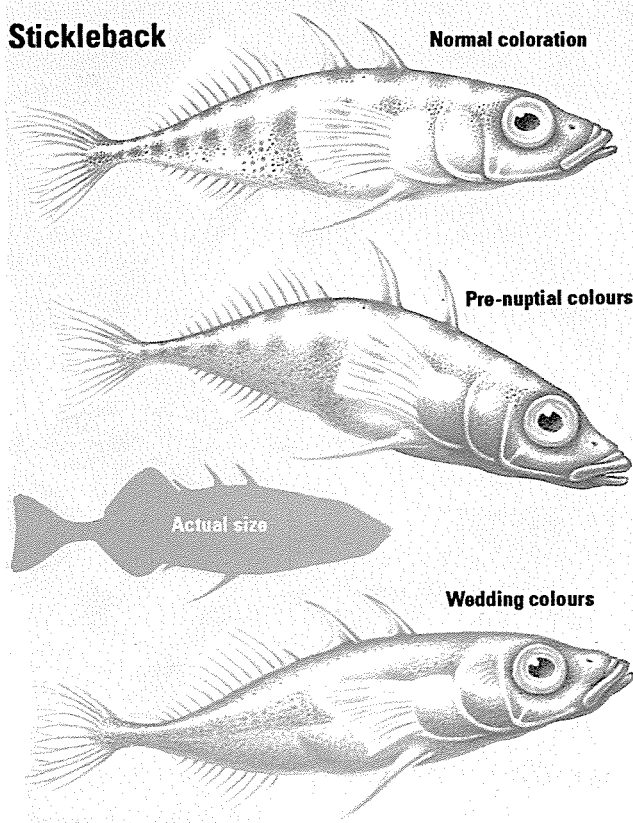
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Stickleback



The male stickleback is usually a neutral colour (top) that blends in with the background. Before mating though, its body reddens (middle) to make the fish conspicuous as it stakes out a territory. When ready to mate, it becomes even more colourful with a blue back to attract a mate.

Just amazing!

THE HEAVY BUNCH

THE PLANT WITH THE BIGGEST FLOWER IS THE SO-CALLED 'STINKING CORPSE' LILY FROM SOUTH-EAST ASIA. IT GROWS UP TO 91 CM ACROSS AND WEIGHS 7 KG.



threat with their brilliant colours. The skin of these small amphibians secretes toxins so powerful that the local Indians use the frogs' poison to tip their blowgun darts.

Instant death

Most dangerous of all is the so-called batrachotoxin obtained from the golden-dart poison frog. Merely touching the back of this five-centimetre-long animal, then putting your finger in your mouth would be enough to cause instant death. The average adult golden-dart poison frog contains just 1 mg of venom, but that is enough to kill 2,200 people.

Being colourful is only useful if the creatures you are trying to warn off have colour vision. Nocturnal animals, or those which burrow in the ground or live in the deep sea, almost certainly see only in black and white. But some daytime insects and all daytime birds can see in colour.

Distasteful

This explains the bright black, orange, and yellow coloration of certain heliconid butterflies that taste horrible to their main predator – birds. One peck and the bird instantly drops its distasteful meal. Being surprisingly tough, the butterfly usually survives the attack and the bird quickly learns

The bird of paradise has colourful plumage, especially around the tail, to help it attract a mate in the poor light of the rainforests of New Guinea.

NATURAL BEAUTY

The tiger lily has a spotted pattern on its petals to attract bees and other insects towards its nectar and its pollen.



Dr Jeremy Burgess/SPL

the warning colours of the foul-tasting insect and avoids it in future.

Flowers may be pretty to look at, but they have not evolved just to adorn our gardens and hedgerows. The real purpose of flowers is to attract and provide a landing pad for pollinating insects.

Colour preferences

Different insects are drawn to different-coloured flowers. Bright coloured red, orange, or pink blossoms tend to draw butterflies, while pale, scented flowers attract moths in the dark.

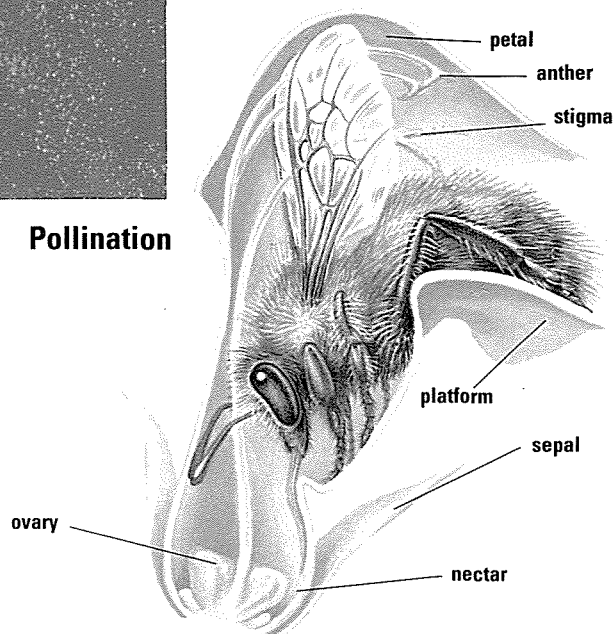
Bees are attracted by flowers. They crawl inside in search of nectar. The anthers – male parts – deposit pollen on its back (right) and the stigma – female parts – pick up pollen brought from other plants.

Pollination

The appearance of a flower to a flying insect, however, may be very different from what human eyes see. Bees, for example, have vision that extends to shorter wavelengths than ours so that they can see the ultraviolet reflected by many flowers.

Pollination

As an insect feeds on the sweet nectar secreted by the flower its body brushes against the pollen on the male parts of the plant, known as the stamens. During the insect's visit to the next flower, some of this pollen rubs off against the female part, or stigma, resulting in pollination.



Mark Iley





The caterpillar of the spidebush swallowtail butterfly has fake eyes to frighten predators.

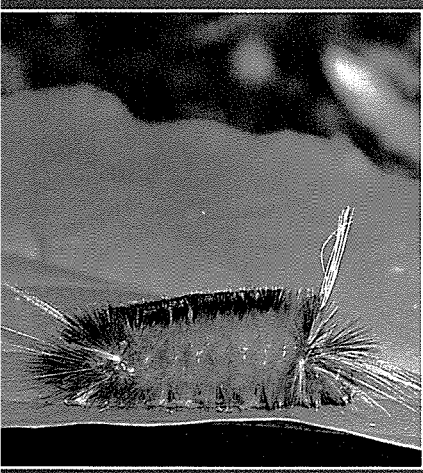
The larvae of the Japanese oak moth are cultivated not for their looks but for their 'wild' silk.

Beautiful but destructive, the caterpillar of the cabbage white butterfly can consume a plant.

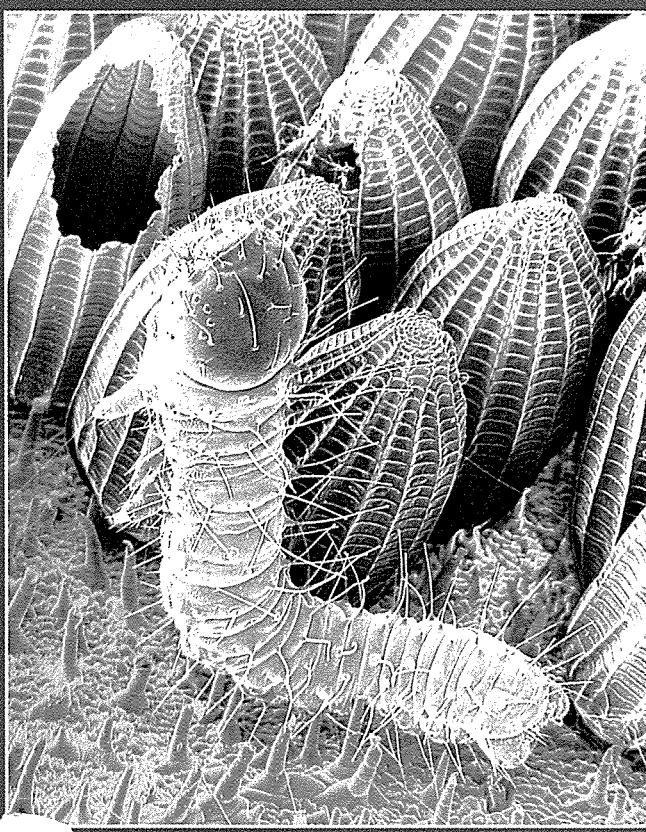


Dr. Jeremy Burgess/SPL

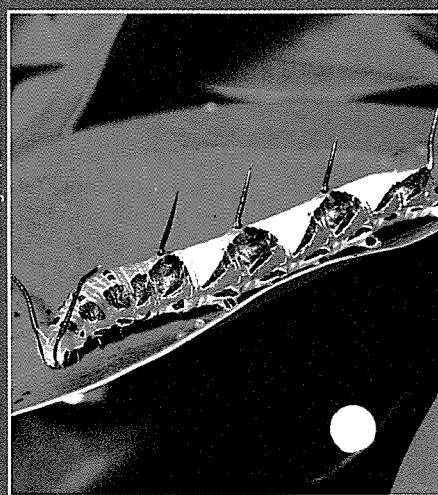
The vivid red colour of this caterpillar from Costa Rica, South America, warns any bird that wants to eat it that it won't make a good meal. It is covered with irritant hairs.



P. Ward/Bruce Coleman Ltd



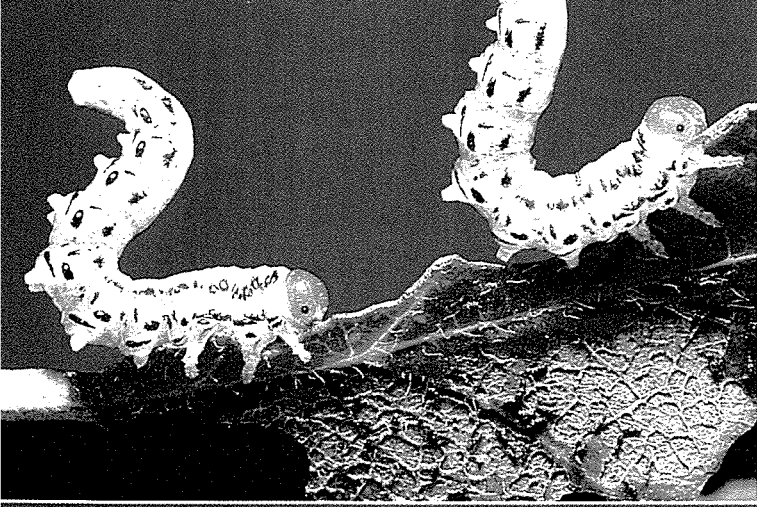
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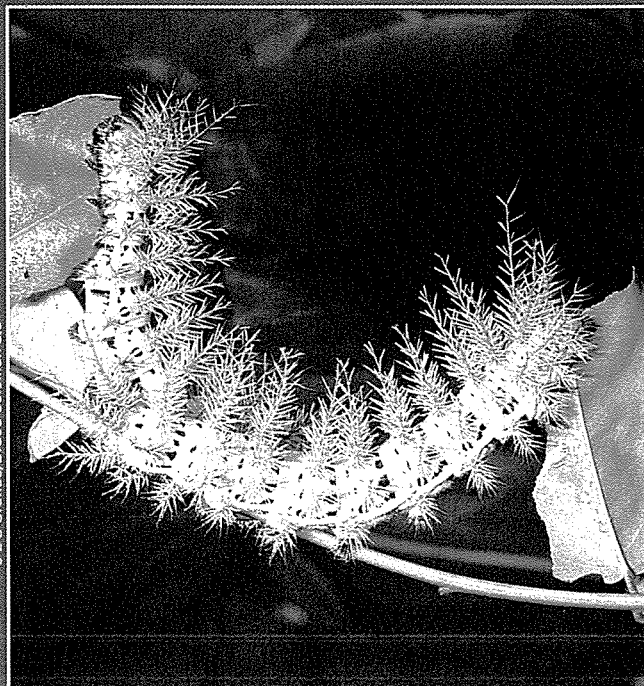
The bright pattern on the body of this rainforest caterpillar from tropical Mexico draws attention to the spikes on its back.

The silkmoth caterpillar from Costa Rica uses its natural beauty, not to warn would-be predators, but to hide itself from predatory birds and other small forest animals.

Caterpillars or larvae do not restrict their natural beauty to the colours and patterns on their heads and bodies. Some are also incredibly graceful in their movements. These two seem to perform an exotic dance as they eat their way along the edge of a leaf.



J. L. G. Grande/Bruce Coleman Ltd



Carol Hughes/Bruce Coleman Ltd

FACING EXTINCTION

ONE OF THE WORLD'S PRETTIEST monkeys, the blind dolphin that inhabits China's Yangtse River and a palm much used by the Ancient Egyptians are among the species most in danger of becoming extinct.

Most endangered species are under threat because of one thing human activity. Sometimes this takes the form of hunting and trapping, but mainly it is because the demands of human civilization or agriculture are overtaking their habitat.

The endangered monkey is the little black tamarin which lives in the wild in only two small patches of forest in the State of São Paulo in

Adelie penguins in Antarctica. The fragile marine ecosystem of the area is endangered by the threat of mining and oil drilling.

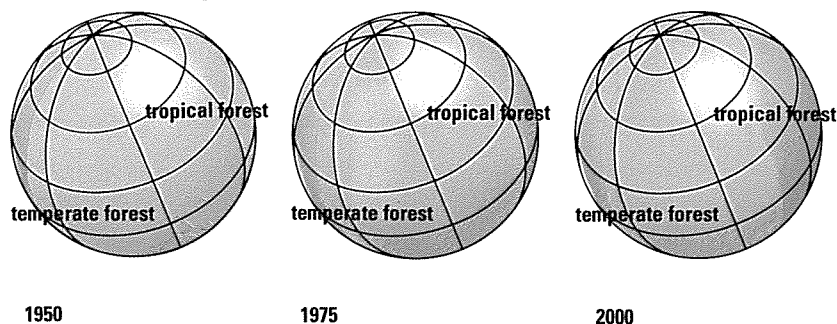
St. Kilda, the Western Isles, Scotland, supports large populations of puffins and gannets and is designated a World Heritage Site.

Tony Stone Photo Library, London

Peter Gathercole/Oxford Scientific Films



The Loss of Tropical Forest



Trevor Hill

Brazil. It is the rarest and most endangered of the New World monkeys, just 100 remain in the wild.

The black tamarin once occupied a large part of the State of São Paulo. But this was one of the first parts of Brazil to be colonized. What was once lush jungle has now been cut down, leaving just a few widely separated tracts of natural forest.

Conservation

Two small groups now live in the Morro do Diabo and Caitetus reserves. In a conservation effort 25 are being kept at the Rio de Janeiro

ZEFA

Primate Centre which contains some of the largest tracts of forest left in the State of Rio de Janeiro.

The baiji dolphin is one of the five species of river dolphins, all of which have very poor eyesight. They don't need acute vision in the muddy waters of the fast-running rivers that they live in. Their other senses though are highly developed and these are used to navigate and find food.

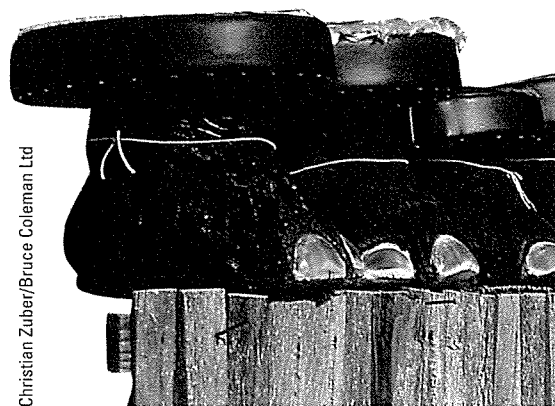
In China's Yangtse River, there are probably less than 400 baiji dolphins left. They are threatened both by fishing and by growing river traffic. The Chinese government is making an

effort to save the species by setting aside a special reserve where fishing and boat traffic will be restricted.

It may already be too late for the argun palm though. Scientists are not even sure if there are any of them left – they were depicted in Ancient Egyptian art and the leaves have

Wildlife's natural habitat is under pressure. The globes show the loss of tropical forest between 1950 and 2000.

Elephant's feet made into stools – a less common example of the exploitation that threatens the elephant's survival.



Christian Zuber/Bruce Coleman Ltd



Tropical fish farming in Florida, USA. Intensive fish farming can have serious consequences for other marine life – seabirds and mammals – as their natural food source is depleted. Salmon farming in Scotland, for example, deprives seabirds of sandeels that are used for fish meal for salmon feed.

traditionally been used to make mats.

Sharks in the waters around the Galapagos Islands were indiscriminately killed, just for their fins which were hacked off for use in exotic dishes including shark fin soup. This was discovered when thousands of shark's carcasses were washed up on nearby beaches. 40,000 sharks were said to be killed this way in 1989.

More than 6,000 species of mammals, birds, reptiles, amphibians, fish, insects and invertebrates are listed as being in danger. An additional 578 are considered vulnerable if present trends continue. Also around 25,000 species of flowering plants are considered to be under threat.

Rare sighting

But all, however, is not gloom and doom. The ivory-billed woodpecker, which was believed to be extinct in the southeast of the US, has been discovered living in Cuba. The purple-plumed bird was forced out of the swampy forests of the lower Mississippi, the large river swamps of the Mississippi Delta, and the cypress swamps of Florida by logging and the removal of the virgin trees they depended on. In the Suwannee River region of Florida, a collector seems to have been responsible for wiping out the remaining population.

The Cuban ivorybill was also under threat by the clearance of forest for sugar plantations. But a recent expedition saw the half-metre long woodpecker eight times in the highlands of eastern Cuba in April 1990. The Cuban government have promised to take action to conserve the ivorybill's remaining habitat.

RA Mittermeier/WWF

A golden lion tamarin, one of the species threatened by the destruction of the South American forests, whose trees are its natural habitat.



Just amazing!

DISAPPEARING HEDGES

SINCE 1947, APPROXIMATELY 306,000 KM OF HEDGES HAVE BEEN DESTROYED IN BRITAIN ALONE – ENOUGH TO SPAN THE EARTH FOUR TIMES OVER.



Paul Raymond



NATURE FIGHTS BACK

WS Paton/Bruce Coleman Ltd

Eric Crichton/Bruce Coleman Ltd

HUMAN INDUSTRY IS AN environmental vandal. But wildlife is more resilient than it is given credit for. Many species thrive on human waste and have taken advantage of the new habitats that industry has provided.

Britain was the country that began the industrial revolution although very few species have become extinct in Britain as a direct result. More habitats have been destroyed by humans through industrialisation cutting down woodlands and hedgerows, by the building of houses and roads and railways and canals.

Wildlife moves back

But wildlife quickly exploited the edges of motorways, for example. And when industry has moved on, abandoning old factories and mines, wildlife quickly moves back. Kestrels

Ospreys in the Everglades National Park in Florida have found the perfect nesting site – the jib of a derelict crane.

Poppies can still take over a wheat field. Despite modern weed killers, many plants become resistant.

raise their young in crumbled factory buildings. Jackdaws nest in disused furnaces and old chimneys. Badgers have taken over underground cellars and tunnels to use as their sets.

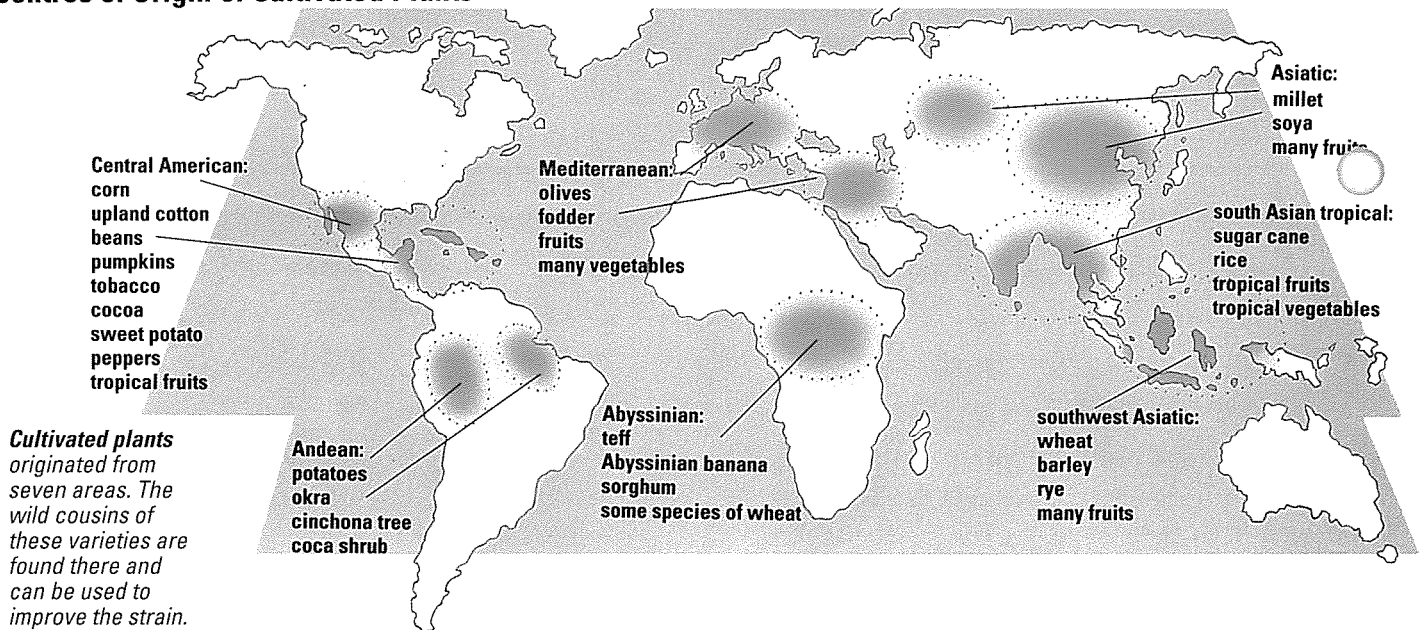
Once an industrial site has become disused, plants quickly take over. Weeds particularly can grow in any crack or exploit any dirt or puddle.

They thrive on poor soil and their roots can crack concrete. And as they grow they enrich the soil, preparing it for other plants to follow.

Orchids often thrive in disused limestone quarries. Mountain mosses quickly colonize old coal mines. Moulds and fungi grow in damp corners or on any decaying waste



Centres of Origin of Cultivated Plants



material. Trees, also, can grow in foundry slack. Birch, willow and, later, oak trees all manage to thrive in industrial wastelands.

Once vegetation has covered the ruins, animal life soon follows. Insects are the first to return. Many species of ants and beetles can thrive even in the most meagre of habitats – living exclusively on rotting wood, dead leaves and other decaying organic matter.

Polecats

Bees, wasps and butterflies are attracted by the flowers, and birds, especially woodpeckers, are quick to follow. Rabbits move in to graze on the new vegetation. And polecats – the wild ancestors of domestic ferrets – move in to prey on them. This is all the more remarkable as a century ago, polecats were on the verge of extinction. They had been ruthlessly exterminated by gamekeepers who saw them as a threat to young partridges and pheasants. Pheasants



Motorways with their towering concrete bridges make a good habitat for the kestrel. It can swoop down on the shrews and mice that inhabit the verges.

Andrew Shaw

Oil seed rape is self-seeding and quickly spreads outside the fields where it is cultivated by farmers, taking over the hedgerows from indigenous flowers.

Michael Leach/NHPA

themselves were brought to Britain from central eastern Asia.

Reclaimed industrial sites are also a haven for badgers, which had been persecuted by farmers who thought they spread tuberculosis to cattle.

Wild boar

Not all the species that return to these former industrial areas are the natural species that lived there before the factories, quarries and mines were built. In England, for example, wolves, bears and wild boar were extinct long before the industrial revolution. In some areas of Europe – notably Portugal – wolves are making something of a comeback though.

The number of native red deer that used to inhabit England has dwindled to the point where they cannot recolonize. Roe deer that were extinct in England in 1800 have been reintroduced. But the fallow deer which were introduced to England from France by the Normans and muntjac deer from India and China have escaped from parklands and now live wild in woodlands in England.

Edible dormice

Tasmanian wallabies have also escaped from zoos in England and are living wild, as is the edible dormouse. Raised to be eaten in Roman times, it

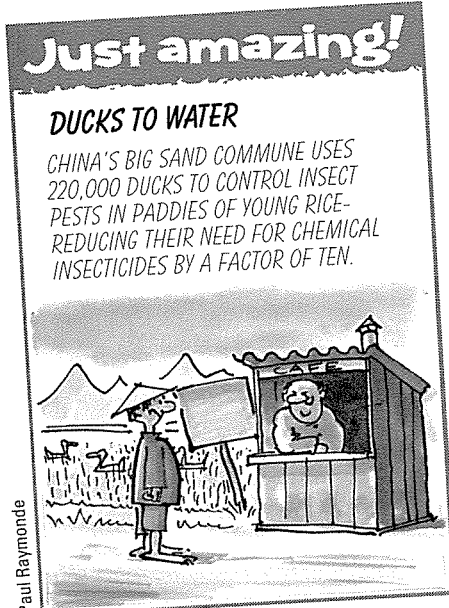


was brought to England in 1902.

Foxes feed on rabbits on old industrial sites, but they have long since accommodated themselves to the ways of man. While they were being killed off in the country, they were making their way up railway lines into the cities where they gorged themselves on the contents of dustbins.

Motorways have produced another new habitat for wildlife. Mink that escaped from farms – where they were reared to make into coats – have used the broad verges to spread themselves across Britain.

Stuart Webb/Oxford Scientific Films





DIGESTION



FOOD AS FUEL



MUSCLE POWER

FUELLING THE BODY

THE ENERGY WE NEED TO move and live comes from the food we eat. But swallowing a mouthful of hamburger or apple is only the beginning of the amazing process of digestion.

Ahead of the food lies a journey lasting about 24 hours through a maze of soft tubes and chambers more than eight metres in length.

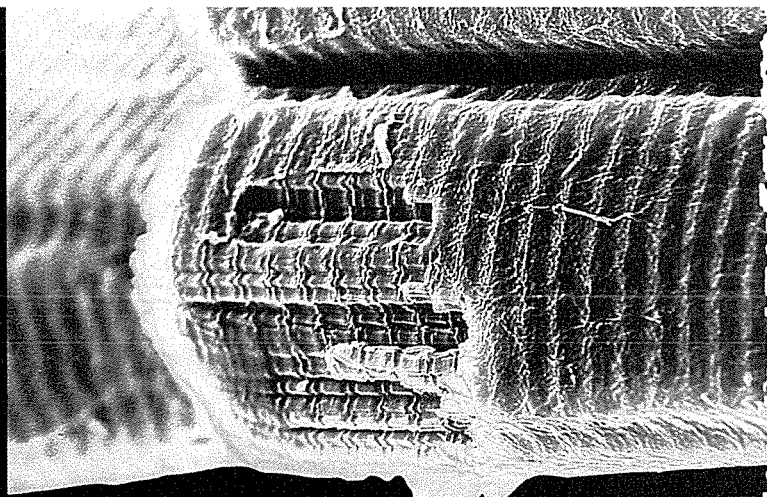


Salivation

Digestion begins in the mouth as the teeth chop up the food into smaller bits and saliva pours in from special glands under the jaws, in front of the ears, and under the tongue. Saliva contains an enzyme – a type of protein – that begins to break the food down and moistens it, so making it easier to swallow.

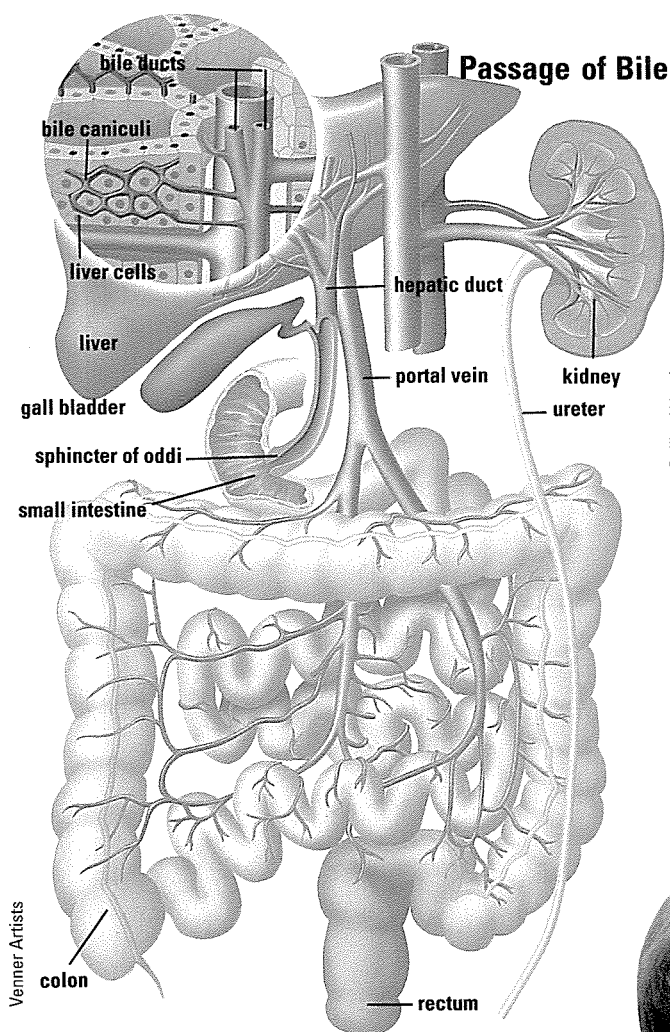
Within seconds, a soggy ball of food is on its way down the oesophagus, a muscular pipe that passes down the throat and into the

A gymnast's muscles are powered by contractions, which are caused by contractile proteins called myofibrils that run along the length of striated muscle fibre (far right). The proteins use energy derived from the breakdown of glucose to carbon dioxide and water.



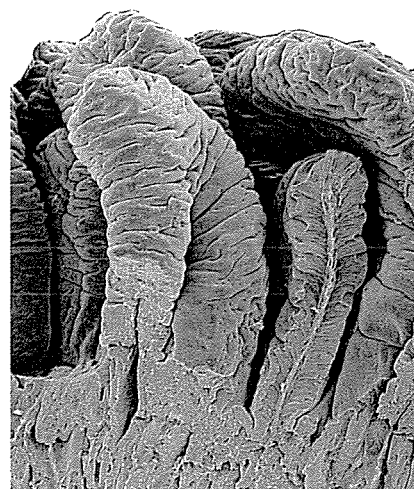
Bob Martin/Allsport





Verrier Artists

Gaillard/Jerrican



In the human digestive system (far left) a litre of bile per day is produced by the liver and released from the small intestine to break down the fats in food. An electron micrograph of the small intestine (left) shows the villi, through which nutrients are absorbed into the bloodstream.

The residue of a hamburger will end up in the large intestine (bottom right) after most of the nutrients (protein, starch etc.) have been chemically processed and absorbed in the small intestine.

the top part of a 6-metre-long tube called the small intestine.

Pipes flow into the duodenum bringing a variety of other substances for breaking down further what remains of the food. Among these substances are bile – a digestive cocktail of thick, bitter, yellow or greenish fluid brewed in the liver. Although over 95 per cent water, it contains a wide range of chemicals including bile salts, mineral salts, cholesterol and bile pigments. The bile salts play a vital part in breaking down fat so the digestive chemicals (enzymes) can then go to work. Other chemicals, produced in the pancreas, neutralize stomach acid and prepare the food for absorption – its passage into the bloodstream.

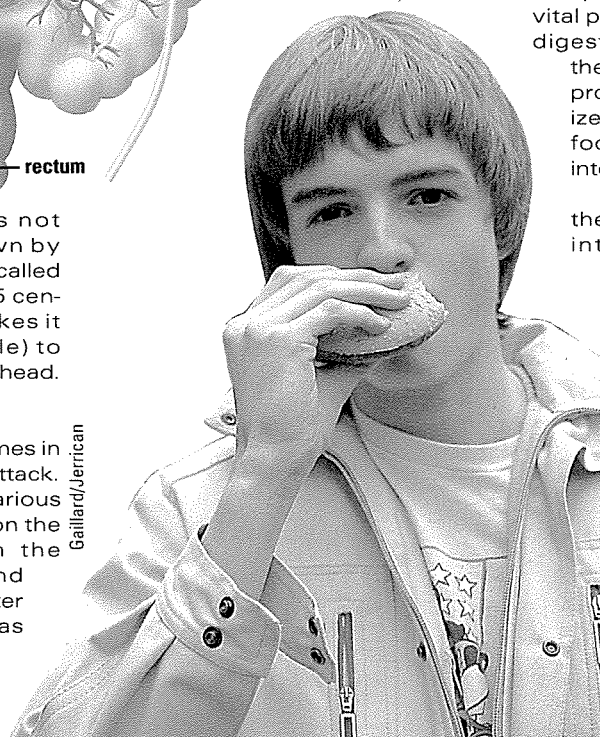
Muscular contractions propel the food remains down the small intestine into regions where thousands of finger-like extensions stick out from the walls. These so-called villi contain a fine network of tiny blood vessels just below their surface. Cells on their surface absorb the useful parts of the digested food – the nutrients – and pass them into the blood.

stomach. But the food does not simply drop. It is pushed down by waves of muscular contraction called peristalsis, travelling at about 5 centimetres per second. This makes it possible (though not sensible) to swallow while standing on your head.

Acid attack

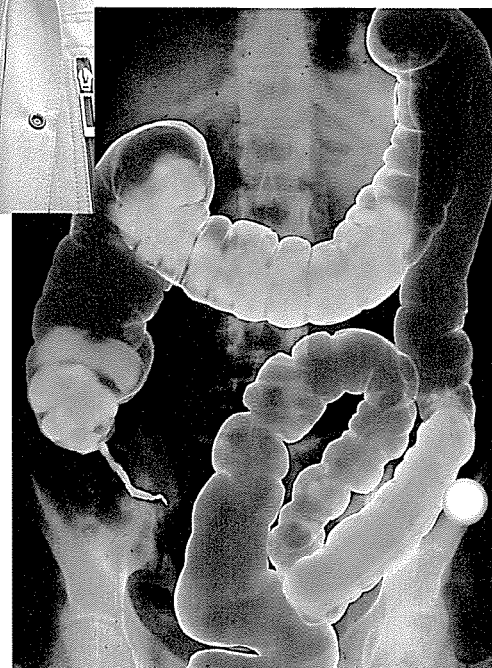
Inside the stomach, the food comes in contact with a fresh chemical attack. Hydrochloric acid, laced with various digestive enzymes, rain down on the meal while the muscles in the stomach wall slowly churn and thoroughly mix the contents. After about two hours, whatever was swallowed resembles pea soup. This greenish liquid is now squeezed out of the stomach into the duodenum,

Gaillard/Jerrican



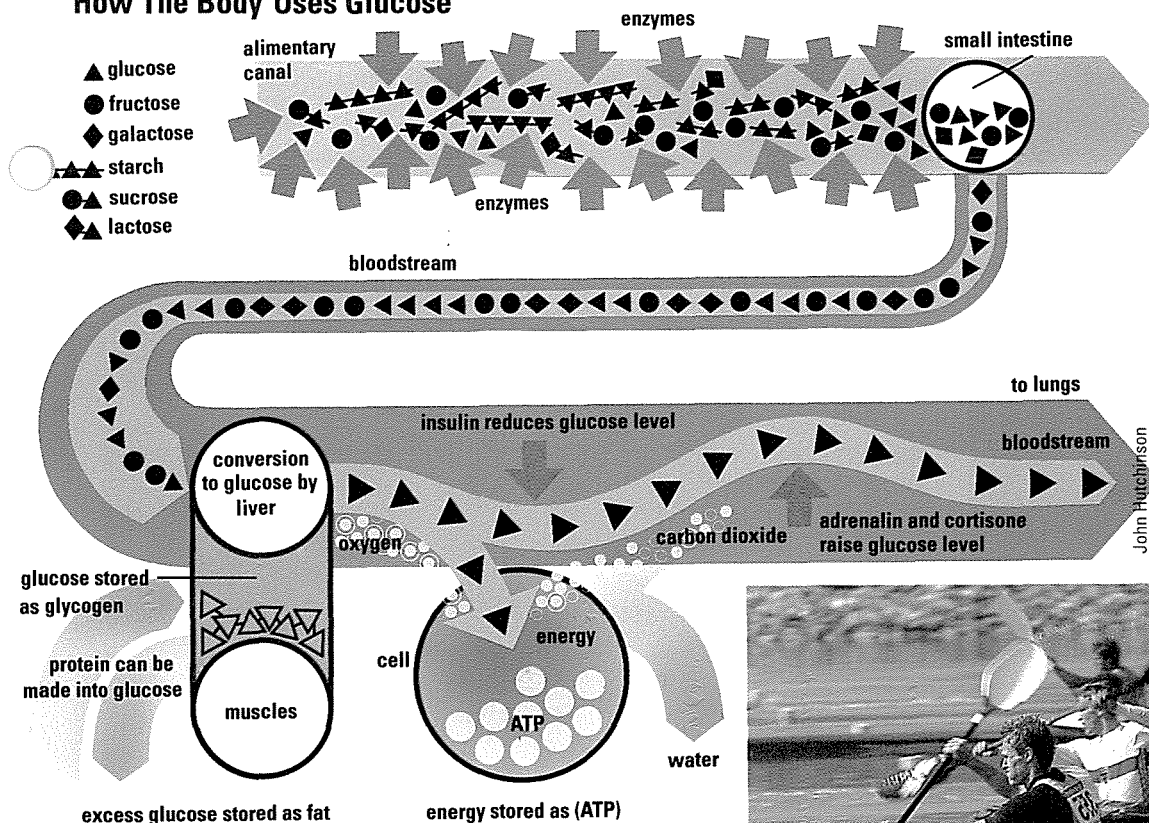
KILOCALORIES (PER 100 GRAMS)

apple	35	cod, fried in batter	199
bacon (streaky)	424	cream, single	212
banana	47	eggs, boiled	144
beans, french	7	ice cream	167
beef (minced)	229	milk, whole, 1 pint (568 ml)	371
beef, grilled steak	218	milk, skimmed, 1 pint (568 ml)	188
bread, white	232	oranges	26
bread, wholemeal	216	potatoes, baked	85
butter	740	potatoes, chips	253
carrots	19	rice, boiled	361
cheese, cheddar	406	spaghetti	378
cheese, cottage	96	tomatoes	14
chicken, roasted	148	wine	67



CNR/SPL

How The Body Uses Glucose



Fuel for muscles to operate (below) is derived from the breakdown of carbohydrates by enzymes to glucose. Once glucose is released into the blood it is taken up by the cells. Inside the cells it is oxidized to produce energy. The cells store this energy by creating high-energy phosphate compounds (ATP – adenosine triphosphate), which act like a battery to be used and recharged.



Meanwhile, what is left-over in the small intestine continues its journey into a wider, 1.5-metre-long-tube known as the large intestine. This serves to extract most of the remaining water from the food remnants and to produce vitamins through the action of bacteria. Finally, the

Vitamin C – ascorbic acid – is essential for the formation of connective tissue and the regulation of tissue respiration.

Starch grains shown in the cells of a mature Jack bean by a false-colour electron micrograph. Starch is converted during the digestive process into simple sugars that can be utilized when needed or stored by the body as fuel.

chemical processing plant for nutrients. Some nutrients it passes on unchanged into the rest of the blood system, others it changes into more useful substances before sending them on or storing them.

The blood system carries the final products of digestion to every cell in the body where the nutrients are put to use. Together with oxygen from the air we breathe, these nutrients are the means by which cells function, repair, and replace themselves.

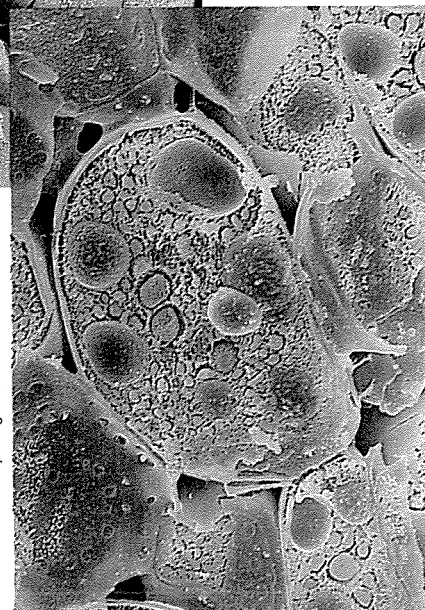
Blood sugar

One way in which the food we eat is used is to operate muscles. The glucose burnt as fuel by the muscles is derived from the breakdown of carbohydrates in the intestine into small sugar molecules. These molecules are absorbed as fructose, galactose and glucose. Glucose is used directly by all cells for energy, while galactose and fructose are converted to glucose in the liver.

Any surplus of glucose in the blood is converted to glycogen and stored in the liver and the muscles until it is needed, or it is converted to fat by the liver and stored in adipose tissue. The percentage of glucose constant in the blood is 0.1. When the level drops the reserves are drawn on. The pancreas regulates the blood

indigestible waste enters the last part of the large intestine ready to be forced out as faeces by the muscular walls of the rectum at the end. Ten to fifty per cent of faeces is dead bacteria, while the rest is mainly water.

Once in the bloodstream, most of the tiny particles of nutrients go straight to the liver along a blood vessel that is the only one in the body that does not start or end at the heart. The liver, as well as being involved in a variety of other jobs, acts as a



sugar level by secreting insulin.

Using refined sugar as a source of instant energy, apart from the risks of tooth decay and obesity, has the drawbacks that sugar is empty of nutrients and can overstimulate the pancreas. It has also been suggested that a high sugar intake increases the risk of diabetes mellitus.

Muscles work by contracting, that

dioxide, and heat. If many muscles are used at once for a considerable period, as in playing football or chopping wood, heat builds up faster than the body can easily get rid of and we start to sweat.

Involuntary movement

Every part of the body has its own set of muscles and, together, all the muscles make up over half the body weight. They range in size from the large muscles in the arm and leg to tiny muscles that control the face and tongue. The bulkiest muscle of the 639 in the human body is the gluteus maximus, or buttock muscle, which

Alcohol dehydrogenase – an oxidising enzyme – represented by a computer graphics model. Hundreds of different enzymes exist and they are involved in almost every chemical reaction in the body, acting as biochemical catalysts.

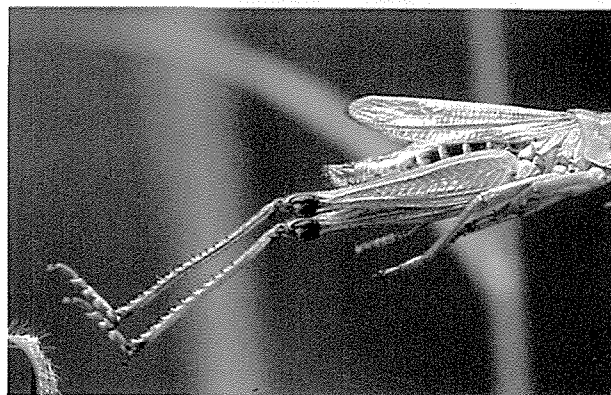
extends to the thigh. This contrasts with the stapedius, which controls the stapes – a tiny bone in the middle ear – which is just 1.3 mm long.

Some muscles are voluntary: which means that you choose when to use them. Many others are involuntary. Sets of involuntary muscles, for example, focus the lens in the eye or push food through the intestines.

The most important involuntary muscles of all are those which make up the wall of the heart – one of the most vital organs for the

HOPPING MAD

Before a grasshopper jumps, it tightly flexes its greatly enlarged back legs. This engages a small catch that effectively locks the leg in position. Then the big muscles inside the leg slowly contract, storing up energy in the same way as a piece of elastic. The muscle contraction itself takes about half a second, while the final leg movement which propels the jump is over in less than three-hundredths of a second. As a result, the elastic energy is released more than ten times faster than it was stored – producing a sudden burst of power.



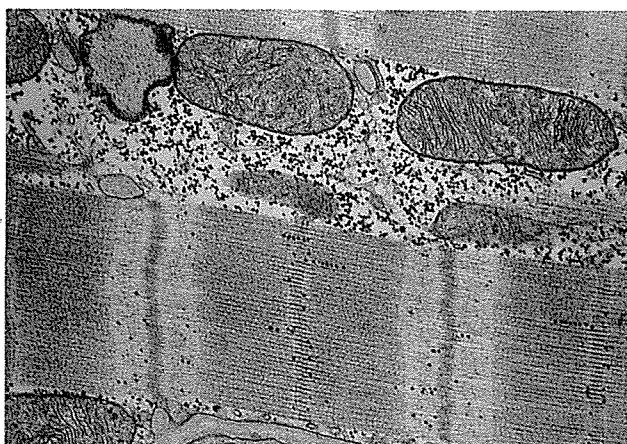
Stephen Dalton/NHPA

Muscle movement, and almost every other action of the body, is controlled from the brain. Involuntary muscles, for example, are co-ordinated by a region of the brain called the cerebellum. A different region, the motor cortex, is responsible for those movements that are under our conscious control.

As well as handling movement, the brain deals with sensations, switches on and off the production of various chemicals throughout the body, and, not least, thinks. So, it is not surprising that the brain must be well supplied with energy. Though it weighs only about 1.5 kilograms – one fiftieth of the body's weight – it uses up one fifth of the body's energy supply.

is by getting shorter and thicker. In most cases, both ends of a muscle are joined to a bone, so that when the muscle contracts the bones move. Since a muscle cannot make itself longer again, a second muscle is needed that works in the opposite direction. So, muscles normally occur in

A cardiac muscle cell, shown by means of a false colour scanning electron micrograph. The small black dots are granules of glycogen. The mitochondria (the elliptical structures along the top) are where glycogen is chemically broken down to yield energy to power muscle contraction.



pairs. For instance, the biceps muscle bends the arm, while the triceps muscle, at the back of the upper arm, straightens it again.

To shorten, muscles need a great deal of energy. This is brought to them in the blood, mostly in the form of sugars like glucose. When the glucose reacts with oxygen, also carried by the blood, it releases chemical energy, waste substances such as carbon

maintenance of life. The human heart weighs over 340 gm and over a 75-year lifespan it beats about two billion times and pumps around 150 million litres of blood. The average resting heart rate of an adult is between 60 and 70 times a minute. This compares with an elephant's heart which beats 30 times a minute and a shrew's which beats 800 times a minute – or more than 10 times a second.

Just amazing!

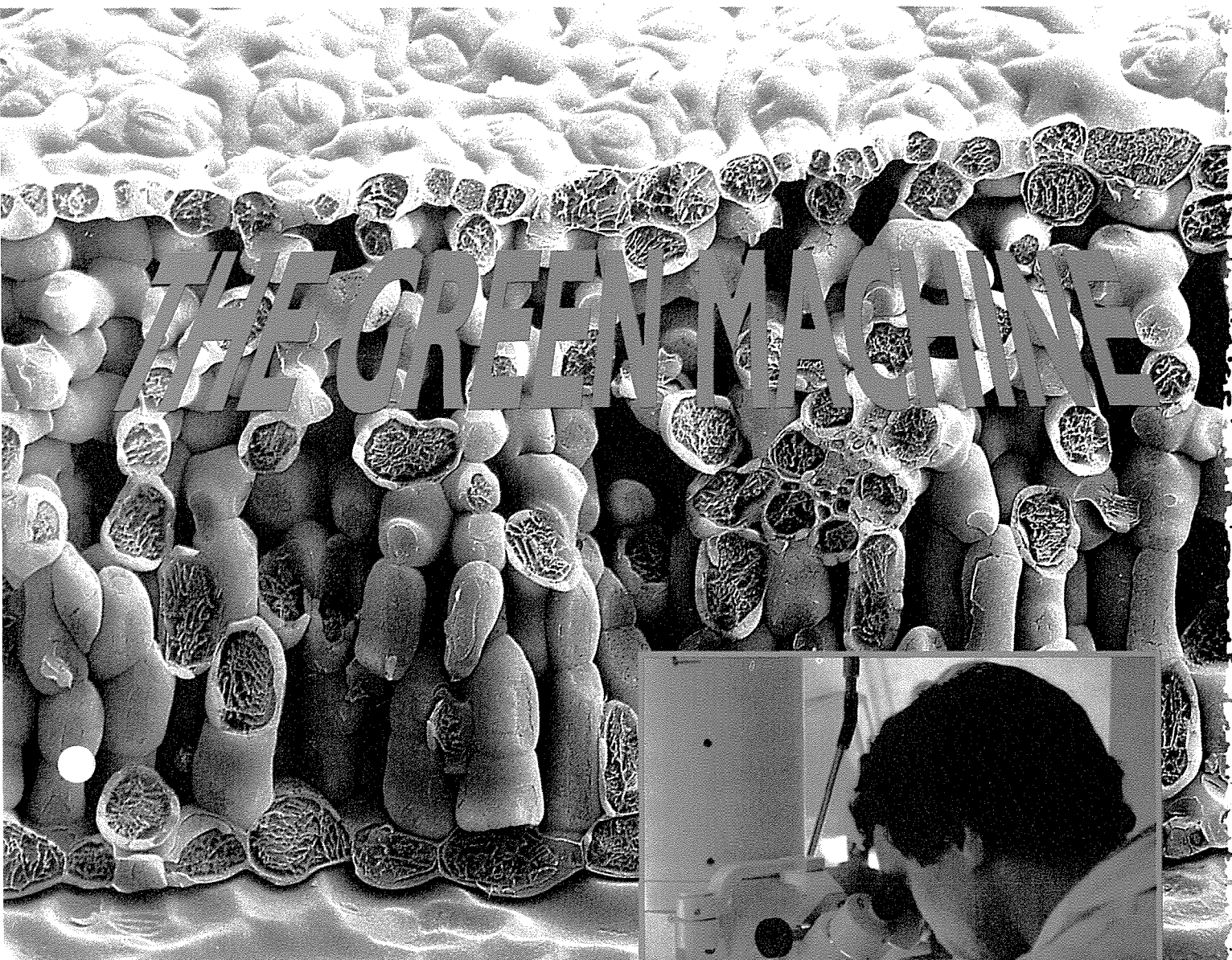
GASTRIC DEUCE

THE HIGHLY-FOLDED INNER LINING OF A HUMAN SMALL INTESTINE HAS AN ESTIMATED AREA OF 250 SQUARE METRES – LARGER THAN A DOUBLES TENNIS COURT.



Paul Raymond

Dan Faurer/SPL



PLANTS HAVE THE AMAZING ability to trap energy from the Sun for use in building the complex chemicals in their cells. This process, known as photosynthesis, is vital to all animals as well, since plants form the basis of the world's food chain and produce the oxygen we need to breathe.

Because most plants do not eat other living things that would provide a source of ready-made food, they must build all the complex chemicals they need from simple substances – carbon dioxide, water and minerals from the soil. Sunlight is the key which makes this possible – photosynthesis literally means 'building from light'.

The energy in sunlight is absorbed by a bright green substance called chlorophyll, which is concentrated mainly in the leaves, inside microscopic objects known as chloroplasts. Carbon dioxide from the air enters through tiny pores, or stomata. In most plants, the stomata are found on the under-surfaces of the leaves.

A turnip leaf section, magnified 57 times by means of an electron microscope (right), showing the layers of tightly packed palisade cells in which photosynthesis takes place.



John Innes Foundation

Water is absorbed from the soil by the roots. It then travels along the roots, up the stem, and into the leaves through narrow tubes called xylem vessels. In the leaves, xylem vessels branch out from the mid-rib as a fine network of veins.

Solar power

Photons (particles of light) are trapped by molecules of chlorophyll contained in neatly folded membranes inside the chloroplasts. The biggest concentration of chloroplasts is in the so-called palisade layer of cells, just below the waterproof upper layer of the leaf.

Each photon that is caught raises the energy level of a chlorophyll molecule. This extra energy is then passed on, via a chain of reactions, to a spongy layer of cells beneath the palisade layer. The energy is carried in relays by tiny, electrically charged particles called electrons.

Carbon dioxide entering through the stomata and water arriving by the xylem vessels also collect in the spongy layer of cells within the leaf. The energetic electrons set free with the help of sunlight react with the carbon dioxide and water to give simple sugars, such as glucose, and oxygen.

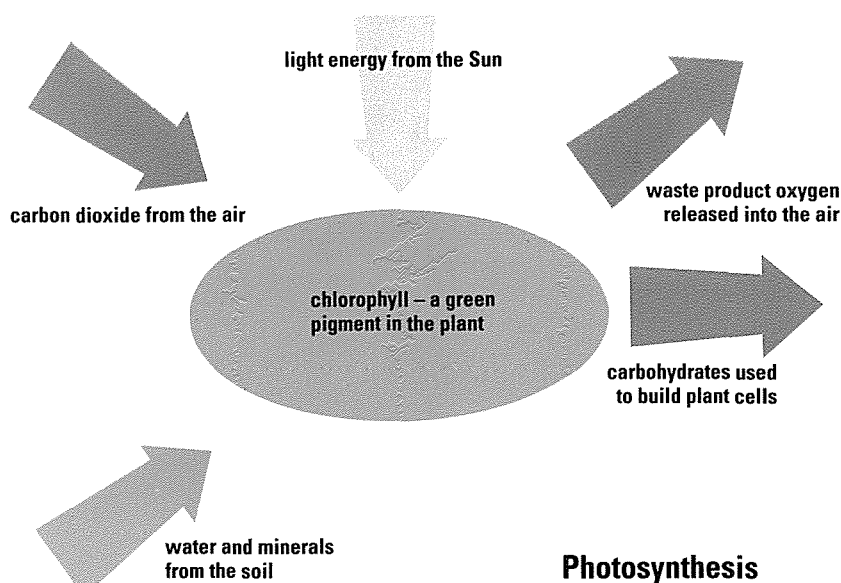


These sugars pass out of the leaves through a second set of tubes running parallel to the xylem vessels. These food-carrying pipelines, or phloem tubes, transport sugars to all parts of the plant.

Body building

Just as steel is a raw material from which cars, refrigerators and many other finished goods are made, these sugars are a basic building stuff for making the living cells of leaves, stems, roots, flowers, fruits and seeds. A plant, however, cannot live on sugar alone. It has to assemble a wide variety of complicated substances – proteins, more complex carbohydrates (including cellulose) and fats – from sugar and from minerals extracted from the soil by its roots.

In the future, scientists hope to be able to mimic the way photosynthesis works in plants to supply some of the



Photosynthesis

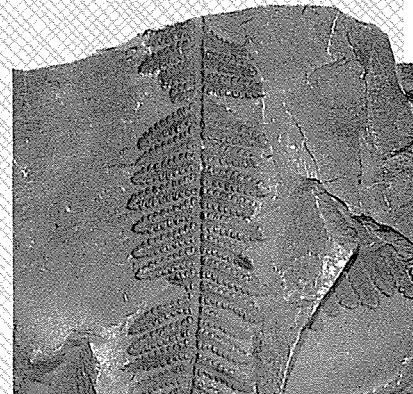
Mark Franklin

Chlorophylls convert solar energy into chemical energy. This changes carbon dioxide and water into oxygen and simple forms of carbohydrates called sugars.

When sugar-cane is burnt to remove the outer leaves before harvesting, energy stored in sucrose form is released as heat energy.

COAL – A FOSSIL FUEL

The solar energy trapped by plants over 300 million years ago, before the age of the dinosaurs, is released today, to warm homes and generate electricity in power stations, when coal is burned. Tall, fern-like plants (below) that grew in swamps during the Carboniferous period used photosynthesis to grow just as modern plants do. After they died, they were buried beneath an increasingly thick layer of mud and peat, until they were crushed into hard, black coal.



D Boyd/GSF

world's energy needs. The goal is to develop an artificial molecule with similar properties to those of chlorophyll. But whereas in plants, the end product of photosynthesis is a sugar such as glucose, in this new, artificial form it would be hydrogen – a fuel that could partly replace coal, oil and

natural gas within the next century.

A molecule that does a similar job to chlorophyll has been synthesized by a team of British, French and American researchers. The middle section of this molecule can absorb a photon of sunlight and, in the process, produce an energetic electron. Normally, such an electron would immediately re-emit a photon, or series of photons, and so lose its energy again. But attached to either end of this new molecule are groups of atoms that prevent this happening. One group quickly snatches the energized electron away. Meanwhile, on the other

side, a second group supplies a fresh electron to plug the hole left behind.

A different approach is to extract the light-harvesting part of a living plant – the chloroplast membranes – and then adapt these to serve human needs. Researchers are looking for a way of splitting water molecules into oxygen and hydrogen, using energy from the Sun. The hydrogen could then be stored and used as a fuel for homes, industry and transport.

A chloroplast in a leaf cell of a garden pea, magnified 1,000 times. In its centre is a starch granule. The strands running through the chloroplast contain chlorophyll pigments that play a vital role in photosynthesis.

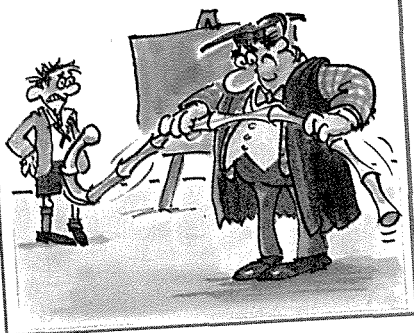
Dr Jeremy Burgess/SPL



Just amazing!

PLANT POWER

THE FASTEST GROWING PLANT IN THE WORLD IS BAMBOO. SO ENERGETIC ARE SOME SPECIES THAT THEY CAN GROW UP TO 41 CM A DAY.



Paul Raymond



STAYING

- EVOLUTION
- KEEPING WARM
- CRYPTOBIOSIS

ALIVE

FROM FROZEN ARCTIC wastes to parched, sun-scorched deserts, many living things manage to survive in the most hostile of environments. Some strange creatures even inhabit the deepest parts of the ocean and streams of superheated water rising from undersea vents.

How does a species develop special characteristics enabling it to

The black swallower fish, in the ocean depths, has developed sharp teeth and extra-strong jaws that enable it to grab prey sometimes larger than itself.

The brown rat is such a successful survivor because it will eat almost anything, animal or vegetable.



Jane Byrton/Bruce Coleman Ltd



survive its surroundings? Within any group of animals and plants, some individuals are better equipped to survive than others. They may be faster, more able to withstand extreme heat or cold, better camouflaged, or have some other advantage over their neighbours. So these individuals are more likely to live long enough to have offspring, some of who will inherit their parents' survival characteristics and pass them on. In this way, a new species gradually evolves that is specially adapted to its environment.

Terrors of the deep

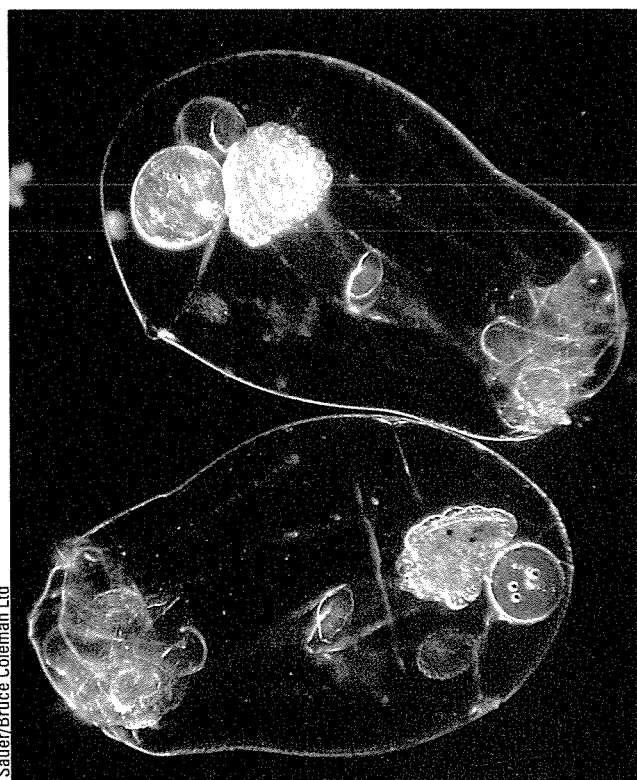
Hundreds of species of fish – large and small – live in the warm, upper layers of the ocean, feeding on each other or on the microscopic plants and animals that thrive in sunlit waters. But below 1,000 metres, in the pitch-black cold, the struggle to survive is intense. Few fish live here, and those that do are often fierce and ugly. At a depth of 2,000 metres, the pressure is equal to the weight of two average men standing on each square centimetre. Yet for creatures living deep in the ocean the big problem is shortage of food.

Frieder Sauer/Bruce Coleman Ltd

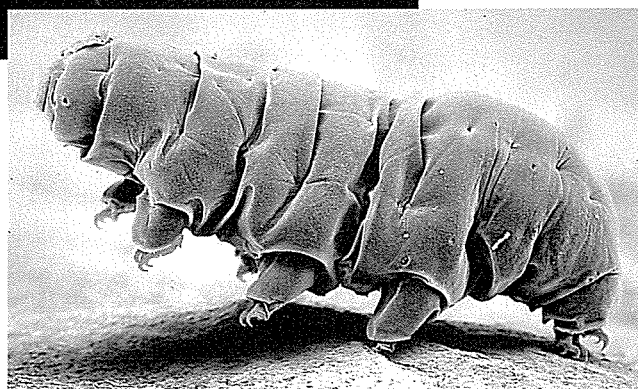
Weird creatures

There is the gulper eel that lures its prey with a reddish light at the end of its tail and then swallows its victim whole through gaping jaws. There is the bizarre chiasmodon, whose belly is so elastic it can stretch to contain fish far larger than itself. And, most

Jawless fish used their weak, circular mouths to suck in particles of food. With jaws, fish can catch and eat much larger prey.

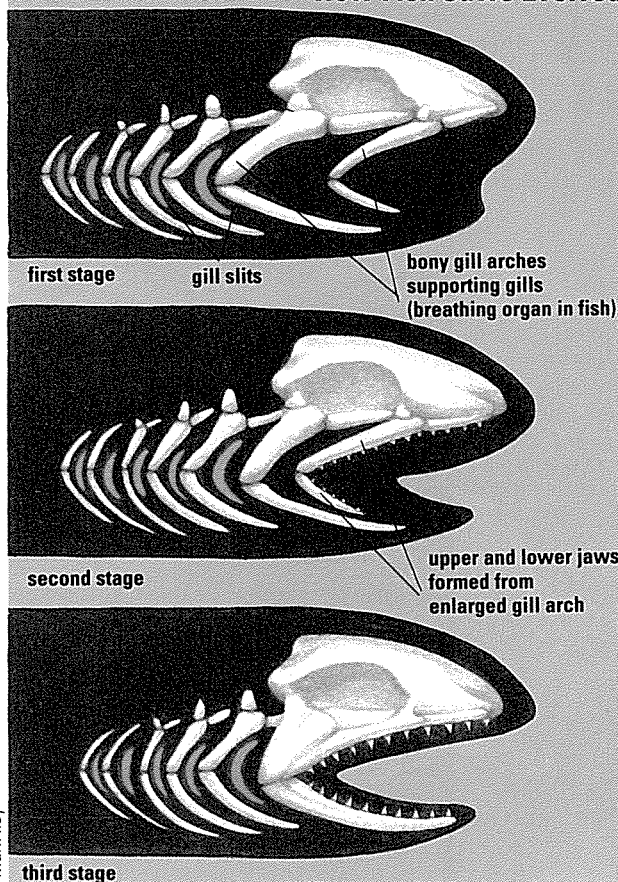


Rotifers and tardigrades (left and below) are both microscopic animals that live in coastal waters, ditches, lakes and clumps of moss. They can survive long periods of drought – even decades – by drying out, until revived by a drop of water. As it dries, the tardigrade's body (below magnified 200 times) contracts into a barrel shape.



Robert Schuster/SF

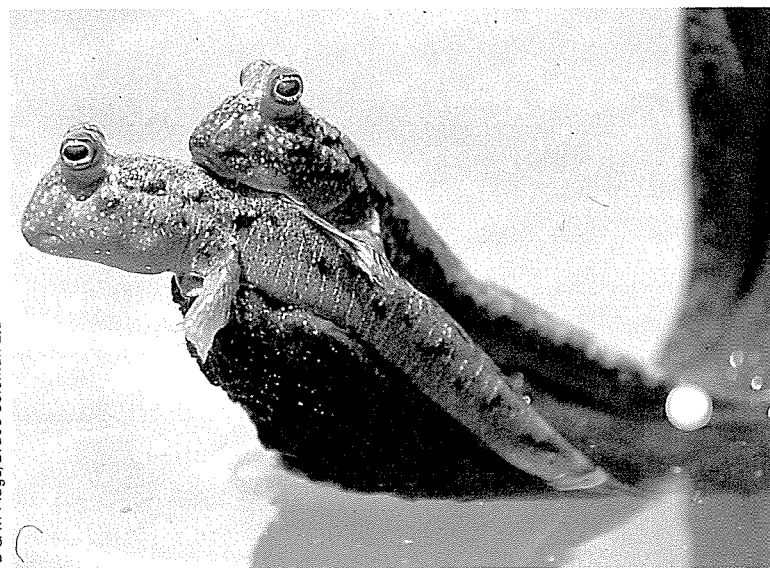
How Fish Jaws Evolved



Mark Iley

Mud-skippers, in the tropics, comb the mud looking for insects to eat. They lever themselves forward over the mud with strong pectoral fins.

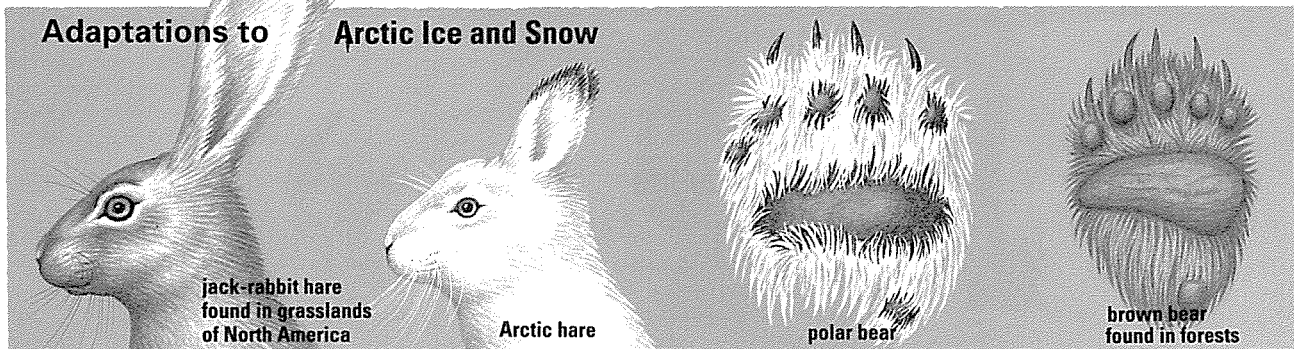
vicious-looking of all, there is the viper fish, with its long jaws of needle-sharp teeth that can snap shut like a steel trap. Yet, despite their frightening appearance, these and other deep-sea fish are actually quite small – between about 10 and 50 cm in length. Bigger fish would simply not find enough to



D & M Plag/Bruce Coleman Ltd



Adaptations to Arctic Ice and Snow



jack-rabbit hare
found in grasslands
of North America

Arctic hare

polar bear

brown bear
found in forests

Mark Iley

An Arctic hare's small ears keep the amount of heat escaping through the skin to a minimum. Spreading feet give greater stability when walking on ice.

eat at these depths.

At the very bottom of the ocean, below 6,000 metres, food is even scarcer. But the animals that live here have adapted to make the most of what falls down from above. A sea urchin, for instance, seems to relish a

pile of dung. Other bottom feeders, like the sea cucumber, eat the organically rich sediment of the ocean floor. Still others scavenge for the dead remains of bigger animals that have drifted down to the ocean floor.

Living in the desert

In the desert, one of the biggest problems is the lack of water. Animals have evolved ways of saving as much water as possible. Insects and reptiles have body coverings that are almost

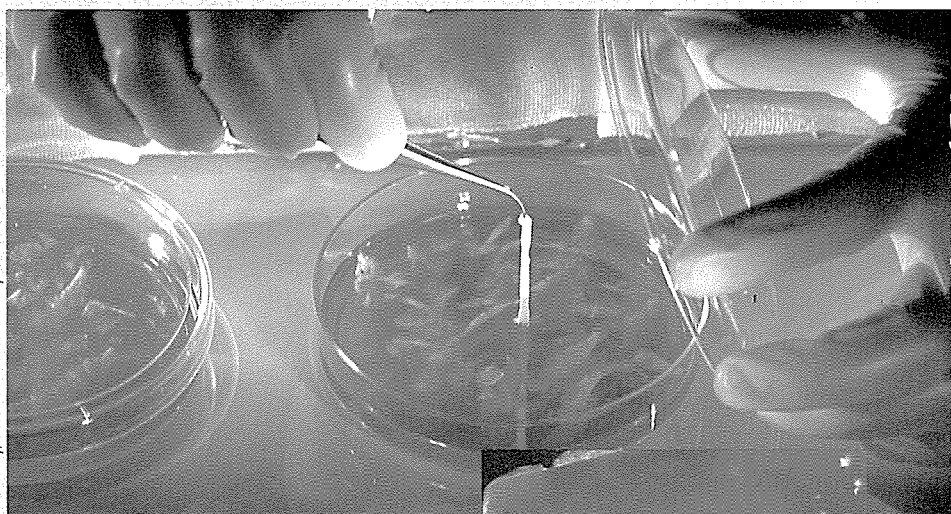
impermeable. The exoskeleton of insects, made of chitin, is covered by a thin, waxy, waterproof outer layer called the epicuticle. A reptile's skin is thick and scaly, without sweat glands.

For warm-blooded animals the problem is more severe. When they are too hot, they must let water evaporate from their skin, by panting or sweating. To compensate, desert-living mammals have specially efficient kidneys that excrete as little water as possible. Many burrow into the sand

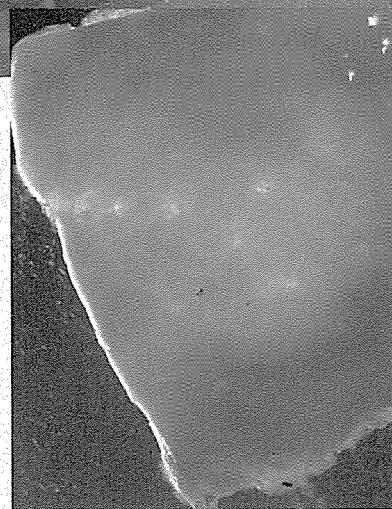
HOW TO REGROW LOST BODY PARTS

Death would come quickly to some animals unless they could replace lost body parts. As a result, these creatures have evolved so they can regenerate missing structures. A crab will regenerate (regrow) a leg or pincer that has been broken off. This is possible because the remaining cells retain a genetic 'memory' or blueprint for building a copy of the missing limb. The larvae of some amphibians can go further. They have the ability to regenerate limbs, tails, jaws and parts of the brain.

Most mammals cannot regrow missing parts – they are more specialized in the healing of wounds. Oddly enough, healing can work against regeneration. New skin and even bandages are believed to hinder the regrowth of severed finger tips in young children.



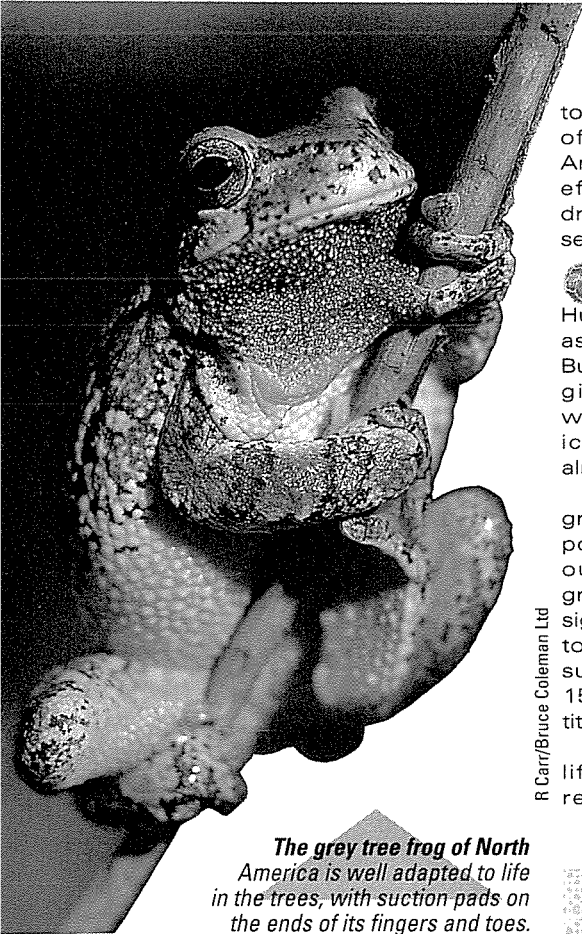
P Pliailly/Science Photo Library



P Pliailly/Science Photo Library

However, Man can now 'grow' artificial skin from a tiny piece of real skin. First, the dermis and epidermis are separated (above) and then cells from the epidermis are 'sown' on to a fragment of dermis. This will develop into a larger section of reconstituted skin.





The grey tree frog of North America is well adapted to life in the trees, with suction pads on the ends of its fingers and toes.

to escape the extreme temperatures of the surface. The kangaroo rat of American deserts conserves water so efficiently that it does not need to drink at all – it can survive on a diet of seeds and insects.

Death in life

Human beings die if they lose as little as a fifth of the water in their bodies. But so-called cryptobiotic animals can give up 99 per cent of their body water and still survive. Their metabolic rate is reduced to a level that is almost undetectable.

One such creature is the tardigrade. Less than 1 mm long, it lives in pools or films of water that may dry out. When this happens, the tardigrade shrivels up, showing almost no signs of life. In this state it is incredibly tough. Dehydrated tardigrades have survived temperatures of 151°C for 15 minutes and 1,000 times the quantity of X-rays that would kill a man.

In one case, tardigrades came to life after a dry chunk of moss was rewetted. The moss had spent the

Other animals, including some species of frog, can actually survive being frozen. The grey tree frog, the spring peeper and the wood frog all hibernate in areas where the winter temperature may fall as low as -10°C. When this happens, over one third of the frog's body fluids freeze solid. In spring, as the temperature rises, the frog gradually revives and continues life as normal.

Bear necessities

Polar bears have their own special adaptations for living on polar ice. A thick layer of fat insulates them from the cold, while huge, rough pads on their feet give them excellent grip. Their fur is a very effective insulator. The outer hairs stand erect like a brush over the dense underfur. Snow does not melt on the outer hairs, although the skin feels warm to the touch. Much of the visible and infrared light from the sun passes through the outer hairs and is absorbed by the skin and a thick layer of air trapped around the woolly underfur.

MICROBES – THE HARDIEST SURVIVORS

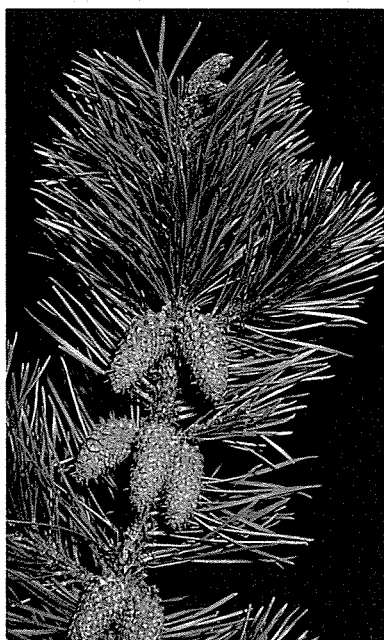


P Ryan/Scriptis/SPL

Some of the smallest living things on Earth are also the toughest. Nearly 2,000-year-old spores of bacteria, for example, have been taken from the Roman fort of Vindolanda, close to Hadrian's Wall, and germinated in the laboratory. Another species of bacteria was discovered in 1982 living in the superheated water spewing from under sea vents known as a 'black smokers'. Water from such a vent (left) has a temperature of up to 300°C – hot enough to destroy the proteins and other complex molecules found in living cells. Yet the new strain of microbe thrived at such temperatures and would die if 'cooled' to 100°C – the normal boiling point of water. Bacteria have also been found floating high in the atmosphere and, in soil, as deep as 8 metres.

OUT OF THE FIRE

Nearly half of the 900,000 hectares of forest in America's Yellowstone National Park was scorched by fires in 1988. Yet almost immediately the richly varied plant and animal life in the park began to recover. Lodgepole pines – the most common tree in Yellowstone – produce two kinds of seed-bearing cones. Some (below) open as soon as they mature. Others can survive the flames of a forest fire and, indeed, will only open after they have been heated, ensuring new growth even when a whole section of forest has burned down.



A-Z Botanical Collection

previous 120 years in a museum! By remaining in cryptobiosis for long periods, it seems, tardigrades, rotifers and other such creatures can extend their lifespans up to 100 times.

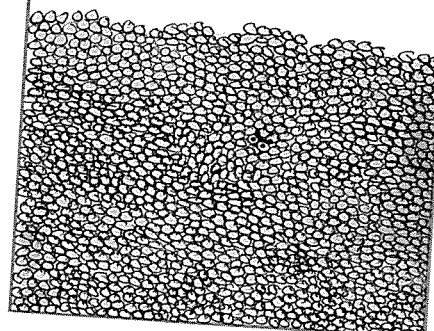
In another instance, a dry tardigrade emerged alive from a scanning electron microscope in which the pressure was as low as a millionth of a millimetre of mercury. Given such powers, it may even be that some cryptobiotic animals and plants could survive the cold, radiation-blasted vacuum of outer Space.

Certain insects and fish that live in polar regions have another incredible survival technique. They produce chemicals, such as glycerol, that lower the freezing point of their body fluids – a kind of natural antifreeze.

Just amazing!

MULTIPLE BIRTH

SURVIVAL FOR SOME SPECIES INVOLVES PRODUCING FANTASTIC NUMBERS OF OFFSPRING. IN ONE SPAWNING, FOR EXAMPLE, AN OCEAN SUNFISH MAY LAY 300 MILLION EGGS.



Paul Raymonde



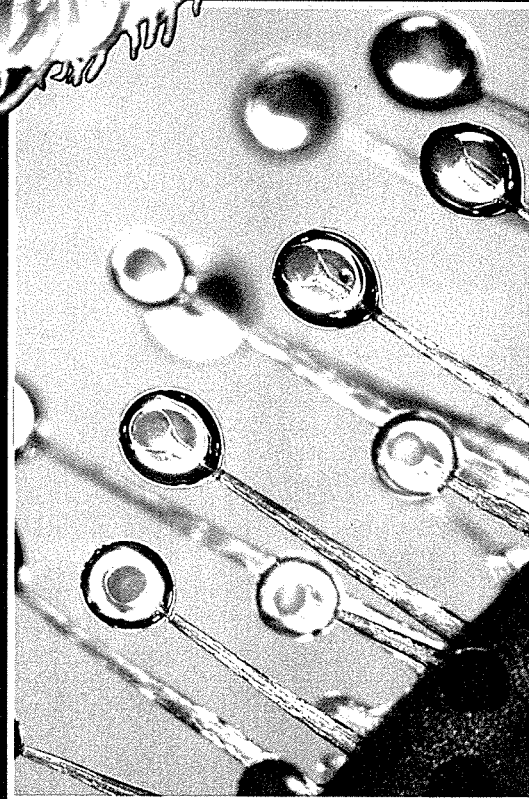
PLANTS IN

MOVEMENT IS A PROPERTY OF all living things - plants as well as animals. The difference is that plants often move so slowly that their motion is hardly noticed.

Most plants are phototropic - that is, they turn their leaves towards the Sun in order to produce food by photosynthesis. One of the most striking examples of this is the sunflower, which follows the path of the Sun as it moves across the sky. Plants also

A common house fly is trapped, wrapped tightly in the curling leaf of the sundew plant to prevent it escaping. The slender

tentacles (inset below), each have a globule of sticky, sugary fluid that attracts and ensnares insects.

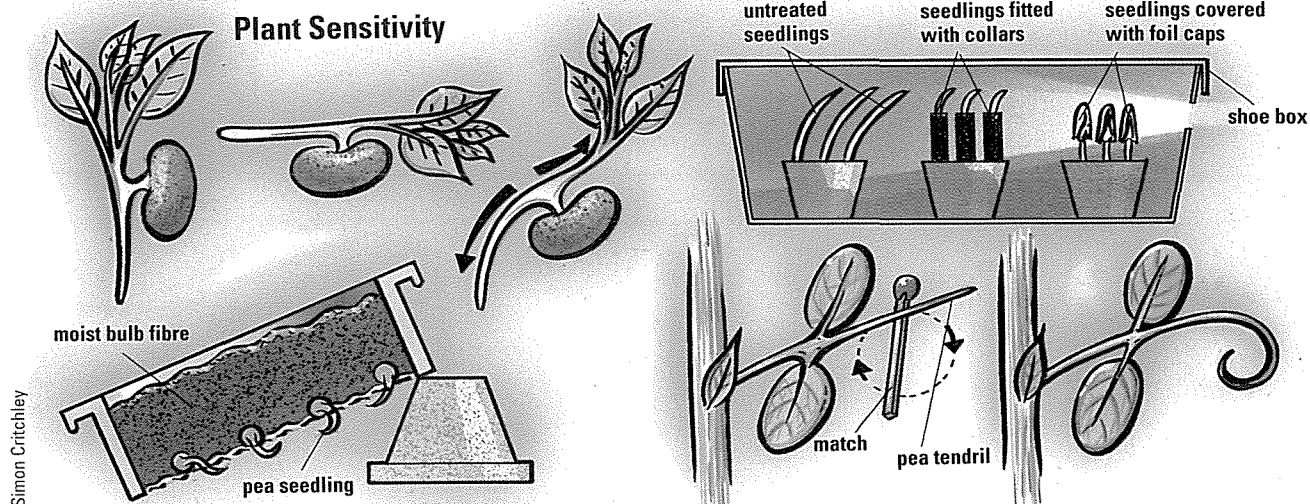


Peter Parks/Oxford Scientific Films

ACTION



Plant Sensitivity



Simon Critchley

A seedling's roots grow down (top left) in response to gravity, but can also grow up to find water (bottom left). Potted plants bend towards light (top right). Vine tendrils curl round anything to gain support for climbing towards light (below right).

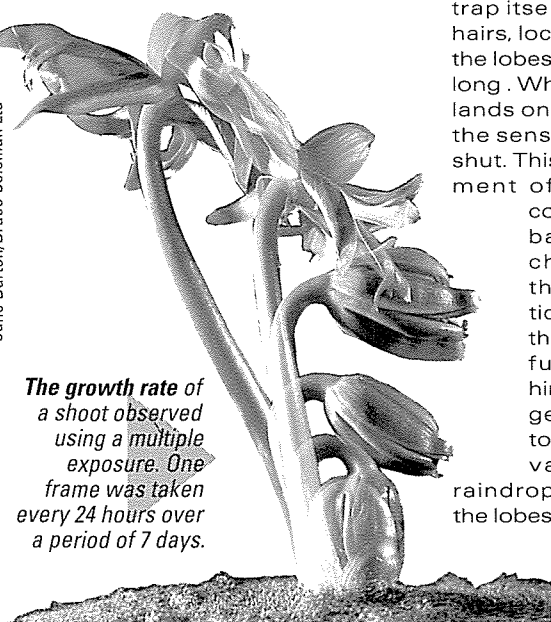
respond to the pull of gravity – an action called geotropism – and to water – an action called hydrotropism.

The leaves of the *Mimosa pudica*, the sensitive plant, are sensitive not only to light. If you touch them they will close up. This movement shakes off insects that are trying to eat their leaves. They can also move quickly to duck out of the way of grazing animals or protect themselves from losing water at night and in cold weather.

Some plants use movement to capture insects, before digesting them and absorbing the nutrients

Jane Burton/Bruce Coleman Ltd

The growth rate of a shoot observed using a multiple exposure. One frame was taken every 24 hours over a period of 7 days.



trap itself is triggered by three stiff hairs, located in a triangle on each of the lobes. The hairs are about 1.5 mm long. When an insect or small animal lands on the leaf or brushes against the sensitive hairs, the leaves snap shut. This occurs because the movement of the hair compresses a constricted zone of cells at its base, producing an electric charge. But it is only when there are two triggering actions in quick succession that the electrical charge is powerful enough to activate the hinge. This 'double action' trigger was probably developed to prevent the trap being activated by, for instance, a raindrop landing on the leaf. When the lobes come together the spines intermesh but do not close totally so small insects can escape. In this way valuable digestive fluid is not wasted on small prey that yield less nutrient than is used digesting it.

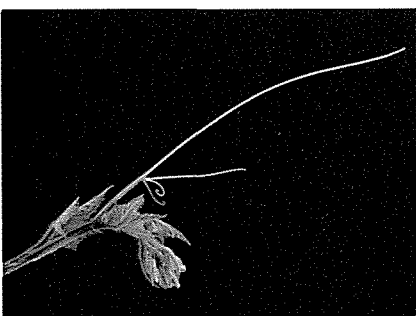


Enzymes

When a larger insect is caught, however, the leaf releases digestive fluids made up of enzymes that dissolve the prey and allow the plant to absorb the nutrients from the victim's body. When the prey is completely digested, the leaf opens again, ready to trap another victim.

Most meat-eating plants live in marshland and bogs where the acidic soil is waterlogged and contains very little nitrate (a chemical rich in nitrogen, which plants need to make protein). Like other plants, they live by

Jane Burton/Bruce Coleman Ltd



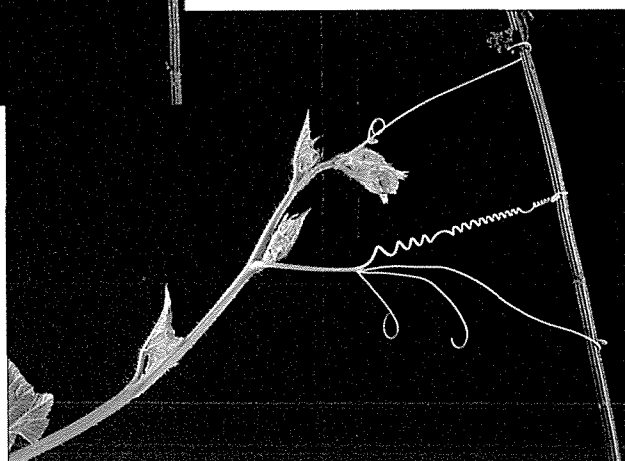
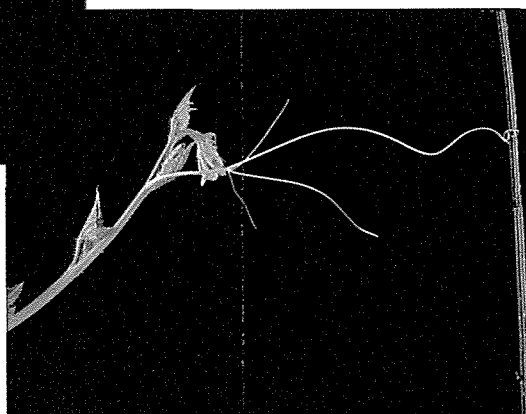
through the leaf surface. Carnivorous plants grow all over the world and in all sorts of climates and conditions. They have five distinct mechanisms for catching their (mainly insect) prey – pitcher traps, snap traps, adhesive traps, suction traps and 'lobster pot' traps.



Snap-trap

The best known snap-trap plant is the Venus fly trap, which can move quickly enough to catch a small frog. The fly trap has leaf stalks that are hinged down the middle rib. The remainder

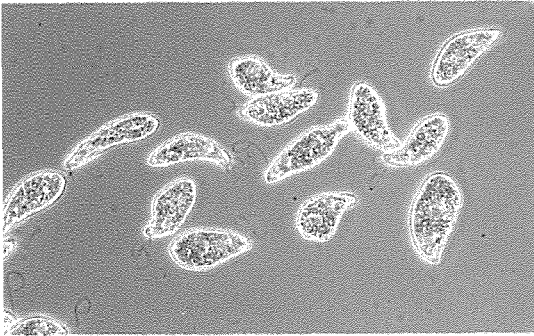
The Ornamental Gourd gains physical support by throwing out tendrils that coil around plants or man-made structures.



PHYTOPLANKTON

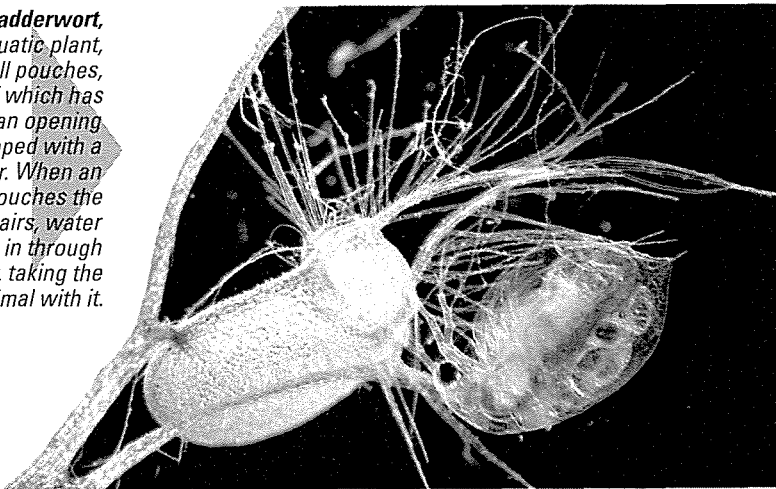
The lowest creatures in the food chain of oceans and rivers are called phytoplankton. Some have tiny whip-like tails – *flagella* – to propel them through the water. Some organisms have both animal and plant-like characteristics. Euglenophyta (below), for instance, can produce their own food by photosynthesis as well as feed off organic material. These organisms consist of a single cell, containing chlorophyll, which accounts for the greenish hue in ponds and aquaria.

Alastair MacEwen/Corbis



The bladderwort, an aquatic plant, has small pouches, each of which has an opening equipped with a trap-door. When an animal touches the trigger hairs, water rushes in through the door, taking the animal with it.

Kim Taylor/Bruce Coleman Ltd



photosynthesizing. But while other plants absorb the nutrient nitrate from the soil, marshland plants must get their nitrate from animals instead. There are over 400 species of plants that prey on animals, mainly insects.

Sticky situation

The sundew plant has stalked glands, in the form of hairs or tentacles, which secrete a viscous, sugary fluid. The tentacles attract and then ensnare any insect that lands on them. As the insect struggles to get free, the tentacles curl over, gluing it even more firmly to the plant. Glands on the tentacles then release digestive juices. When the meal is over, the plant uncurls its tentacles and lets the undigested parts of the insect blow away. It takes about a day, for example, for a Portuguese sundew to eat and digest a whole mosquito.

The bladderwort, an aquatic, rootless plant, uses movement to trap its victims underwater. The bladderwort floats on moorland ponds. Small hol-

low pouches – or bladders – grow on the stem underwater. They are sealed by a trap door. When water fleas or other tiny animals, such as protozoa or insect larvae, touch the sensitive hairs on the trap door, it springs open. The vacuum inside causes water to rush in, sweeping the victim in with it. The door closes and the walls of the bladder begin to produce digestive juices that kill and dissolve the animal and the trap is reset.

Plant colonies

When plants reproduce, the young cannot grow in the same place as its parents. Some plants simply send out shoots with mini-plantlets on the end of them, forming huge colonies. But most plants are more ambitious and want to spread their seeds over a much wider area.

The coconut, for example, floats away from its parent plant on ocean

The leaves of the Venus fly-trap snap shut when an insect brushes against its trigger hairs. Once activated, the trap closes within one fifth of a second.

currents. The hollow centre and the fibrous layer help them stay afloat and they may drift for months until washed ashore. The squirting cucumber on the other hand bursts open, shooting its seeds out like bullets. They can fly at up to 100 km/h and land up to 8 metres away.

Parachutes

Many plants depend on the wind to carry their seeds away. The dandelion and milkweed have small parachutes of fine white fibres that catch any breeze. They can float on the wind for

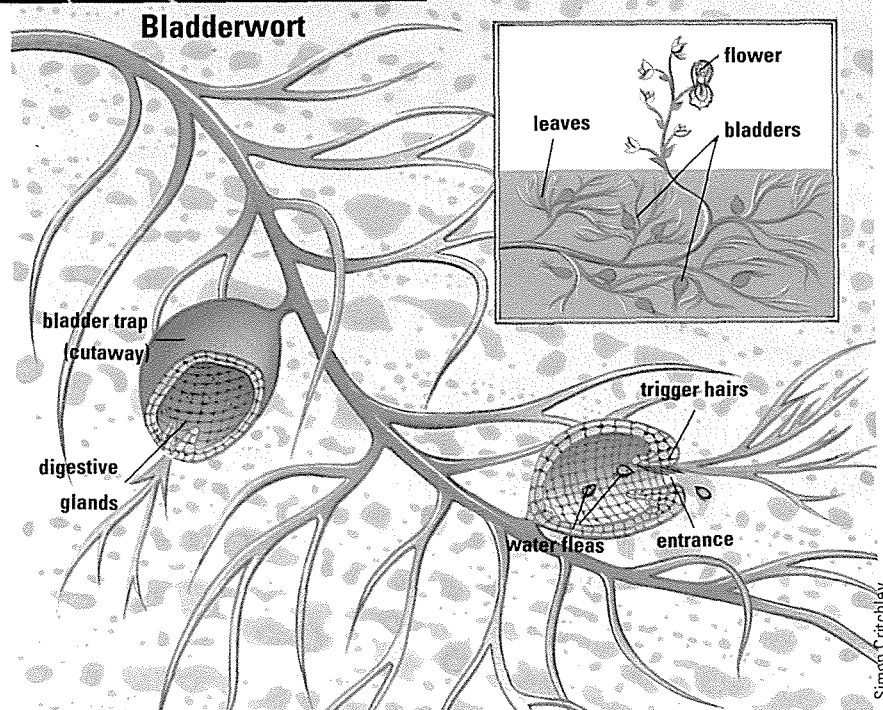


Kim Taylor/Bruce Coleman Ltd

many kilometres. The fibres of the milkweed are so light that they have even been used to fill life jackets to keep people afloat in water.

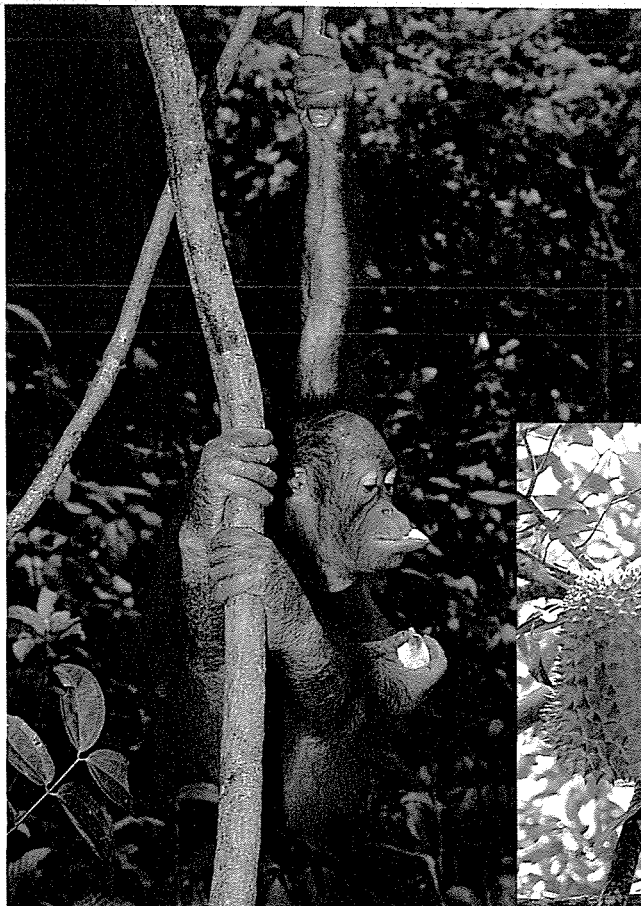
Propellers

The ash and the sycamore have tiny propellers attached to their seeds. When the seed falls from the tree, the propeller begins to turn, giving the seed a helicopter-like lift and helping it



Simon Critchley





Orang-utans are attracted to the smell of Durian fruit (below). The orang-utan eats the flesh surrounding the hard seeds, which pass through the animal's body and are dispersed in its droppings many kilometres away.



N Cattlin/Holt Studios

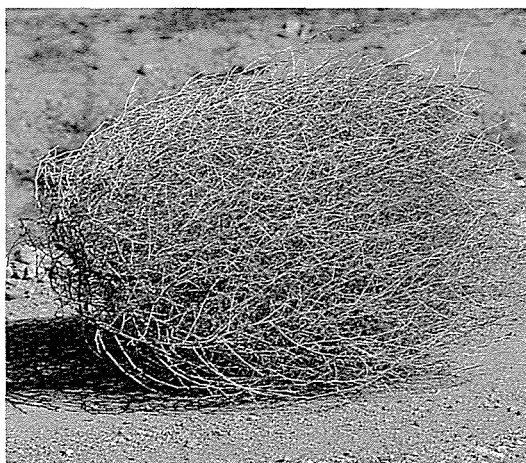
to float on the wind far from the tree.

The seeds of the chinese lantern poppy grow inside a pod that catches the wind like a kite. The pod eventually bursts open, dispersing the seeds over a wide area.

Seed spreaders

Other plants use the movement of animals to spread their seeds. Fruit, for example, is designed to attract animals. They eat it and carry the seeds away in their stomachs, dispersing them in their droppings often a long way from the parent plant. The durian fruit, which can grow to the size of a football, attracts the orang-utan with its smell.

The peony hedges its bets: it has two types of seed – one bright pink,



Tumbleweed is a general term for plants that break free from their roots and are rolled around by the wind, scattering their seeds along the way.

Bruce Coleman Ltd

fel Tower. The rafflesia's huge flower – the only part of the plant that appears above ground – has no green leaves to make its own food because all of its nutrients are 'stolen' from the liana. The liana survives by sending thick rope-like stems to its flowers, growing in the sunlight on top of giant jungle trees. Specially adapted cells transport water through its stems at a rate of 1.5 metres a minute.

JUMPING BEANS

People used to think that the Mexican jumping bean jumped of its own accord to move away from its parent plant. In fact, it does not move by itself. The beans are the seeds of certain Mexican shrubs. A small moth (the *Carpocapsa saltitans*) infests these plants and produces larvae, which spin cocoons inside the seeds and give them the familiar jumping movement. The movement of the caterpillar as it eats the pulp inside the seed also causes the seeds to move. The 'jumping' becomes more evident if the seeds are warmed up by the Sun.

one blue. The bright pink ones attract birds, but cannot grow into a new plant. The birds, though, eat all the seeds and the blue ones pass through the intestine unharmed and grow when they pass out with the droppings of the birds.

Hitch-hooking

Burdock seeds hitch a ride on animals' fur. They have tiny hooks which attach themselves to the coat of a passing animal. The seeds may be several kilometres away before the animal scratches them off.

Seeds also stick to the mud on the feet of animals and birds. Charles Darwin – who put forward the theory of evolution – once grew some 80 plants from seeds he found in the mud on a bird's foot.

Some species of plant have no chlorophyll with which to capture the

Just amazing!

MIGHTY MUSHROOM

NOTHING CAN STOP THE INK CAP FUNGI. IT IS STRONG ENOUGH TO BREAK THROUGH ASPHALT AND LIFT PAVING STONES.



Paul Raymond





Q THE HEART

Q THE LUNGS

PRYER LIFE

The interior of an artery in the human liver, magnified 3,000 times, showing white blood cells stuck to the inner surface. A section of a human lung (right, magnified 1,100 times) shows red blood cells inside a tiny blood vessel, surrounded by a network of air sacs (alveoli).

BLOOD IS THE VERY PULSE OF LIFE. Its motion around the body not only brings oxygen and nutrients to every cell but also carries away the waste matter.

- Blood has five major components:
- The fluid base of the blood is called plasma. It carries food and waste dissolved in solution.
- Disc-shaped red blood cells carry oxygen. It is the red blood cells that make blood appear red. There are about five and a half million cells in a cubic millimetre of blood.
- It is the substance that carries the oxygen, *haemoglobin*, that makes the blood cells red. Red blood cells are replaced every four months or so. Most new blood cells are manufactured in the bone marrow.

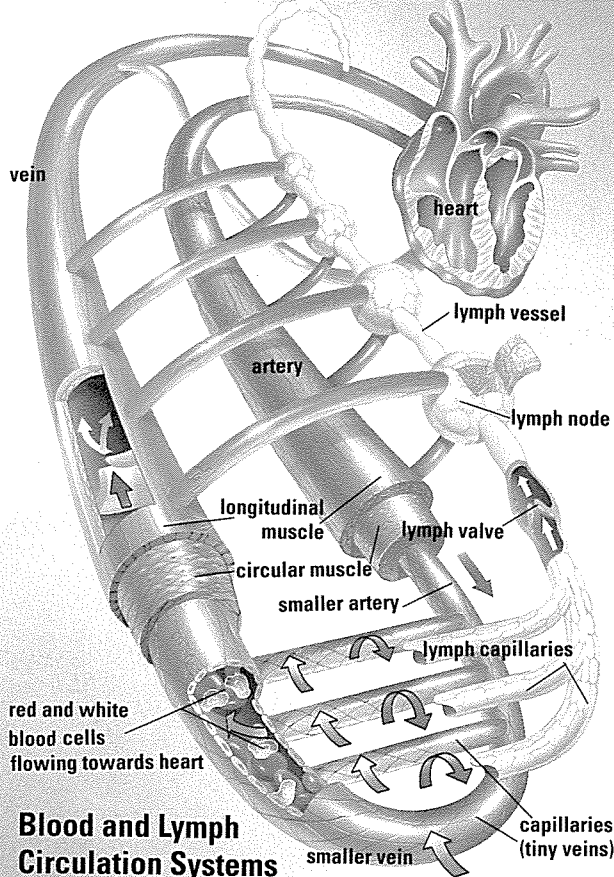
CNR/Science Photo Library

...its are ... than red ones, ... them by ... they eat up ... bacteria in the ... protect the body from dis ... just for only ... are tiny fragments of ... arelets. If a blood vessel is damaged, they stick to the cut and form a plug. They also release enzymes that make the blood clot.

Heart to heart

Blood is pumped around the body by the heart, which is not one pump but two. The right side of the heart pumps blood in from the body and pumps it into the lungs. The left side takes in blood returning from the lungs and pumps it out to the body. The





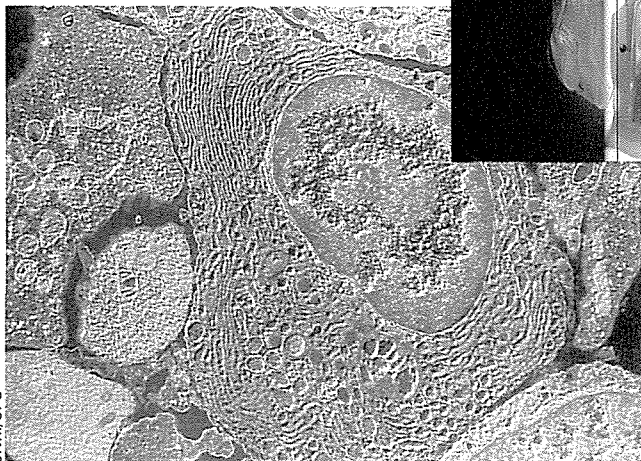
Blood and Lymph Circulation Systems

Joe Lawrence

heart pumps about 9,000 litres of blood every day and beats some 40 million times a year.

Each side of the heart has two chambers. The upper one, which draws the blood into the heart, is called the *atrium* and the lower one, which pumps the blood out of the heart, is called the *ventricle*.

The walls of these chambers are made of muscle. They contract regularly, squeezing the blood through the heart. Between the upper and lower chambers are two valves – the *mitral valve* on the left-hand side and the



CNRI/SPL

tricuspid valve on the right – that prevent blood flowing backwards from the ventricles to the atria.

Red blood cells carry oxygen from the lungs to every cell in the body. They also pick up carbon dioxide, a waste product of cell function, from the cells and take it to the lungs.

When you breathe, air is drawn into the lungs. It passes down tubes



Philippe Plailly/SPL

A plasma cell (here magnified 6,050 times) is a type of white blood cell called a lymphocyte. Produced in the lymph nodes and spleen, they make antibodies that fight infection.

that branch into finer and finer tubes. These end in tiny air sacs, called *aveoli*. Tiny blood vessels surround the *aveoli* and oxygen passes from the air sac into the blood. At the same time carbon dioxide is released from the blood and passes through into the *aveoli*, where it is breathed out. The lungs can hold up to 6 litres of air.

It is blood that picks up food from

Blood is pumped around the body by the heart. Arteries take blood away from the heart and veins carry the blood back again. The lymph vessels return fluid from tissues to the blood system. Lymph nodes filter bacteria and other debris from this lymph fluid.

To remove plasma – the solution in which all blood cells float – from blood, the blood is stored in a bag until the cells have settled at the bottom. Plasma is drawn off the top and the blood cells transfused back into the patient.

the small intestine. (The small intestine is not small at all, it is just narrow compared with the large intestine that follows it. The small intestine, however, is much longer – 6.6 metres compared with the 1.5-metre-long large intestine.)

Around five million small finger-like

NARROWED ARTERIES

Eating a diet of fried food or too many animal fats can cause narrowing of the arteries. Saturated fats produce cholesterol in the blood. This, together with calcium, blood cells and blood clotting agents, builds up along the inner walls of the arteries. The restricted flow of blood along narrowed arteries puts the heart under a lot of strain. To circulate the blood at the same rate as before, it must pump much harder. If the main artery carrying blood to the heart is blocked, it will stop pumping altogether.

structures called *villi* project from the walls of the small intestine, giving it a surface area of 10 square metres – the size of two table tennis tables. Villi are covered by tiny blood vessels with walls just one cell thick. Digested food passes through these thin walls into the bloodstream very easily.

Supplying the cells

Plasma carries many vital chemicals around the body, including sugars, fats, proteins, vitamins and minerals – in fact, all the constituents needed for cell function and renewal. It also carries hormones, made by endocrine glands, to the organs where they are needed. Hormones control growth and sexual reproduction, and prepare the body to fight or run away.

As it circulates, blood passes through the kidneys, where poisonous waste products, such as urea and uric acid, are removed from the blood, together with salts and excess water. Finally, these are all excreted from the body as urine.

Just amazing!

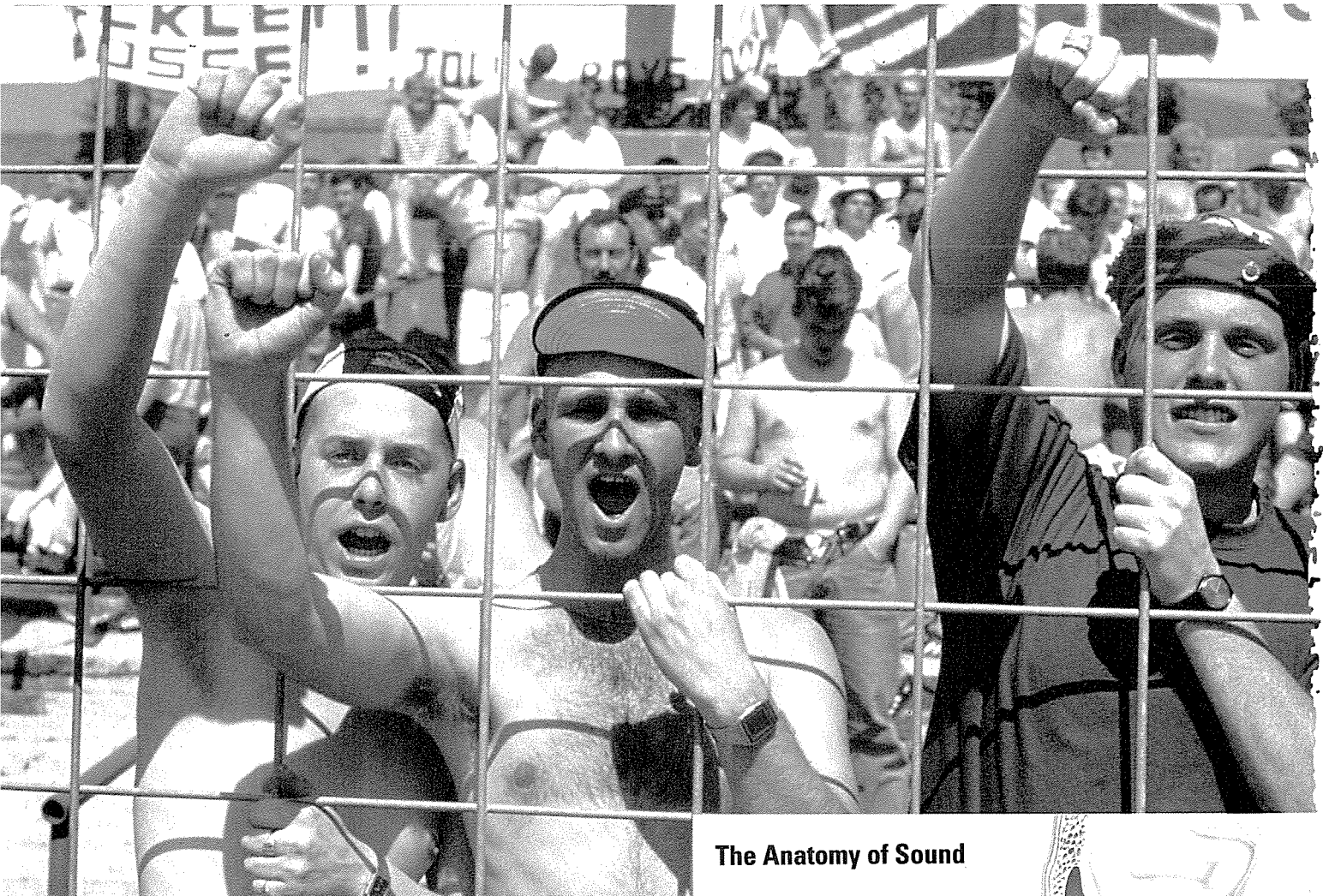
STRUNG OUT

IF ALL THE CAPILLARIES IN YOUR BODY WERE LAID END TO END, THEY WOULD STRETCH COMPLETELY AROUND THE WORLD – TWICE.

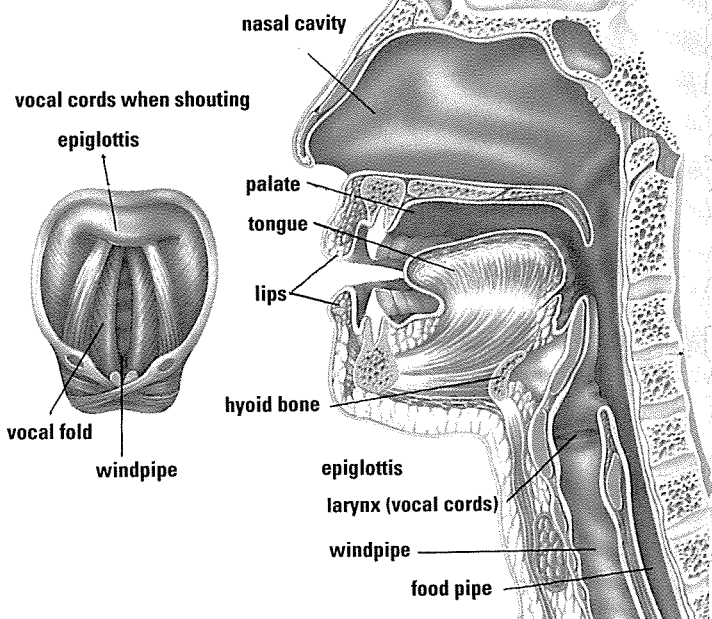


Paul Raymond





The Anatomy of Sound



Leeds United Football fans demonstrate ritualistic aggression by verbal chanting and threatening gestures. When we shout, we force air through the flaps of muscle (inset above) stretched across the top of the windpipe called the vocal cords.

SPEECH IS THE MOST powerful and complex form of communication. But although human beings are masters of the spoken word, other animals can also communicate, using a variety of sounds.

The most important part of the body involved in speech is the larynx, or Adam's apple. This is a complicated structure of thin bone, cartilage (gristle) and muscles, located in the neck at the top of the windpipe. Stretched across the centre of the larynx are two muscular flaps – the

Kate Scott

SPEAK UP

- Q HUMAN SPEECH
- Q INTONATION
- Q VOCAL IMITATION



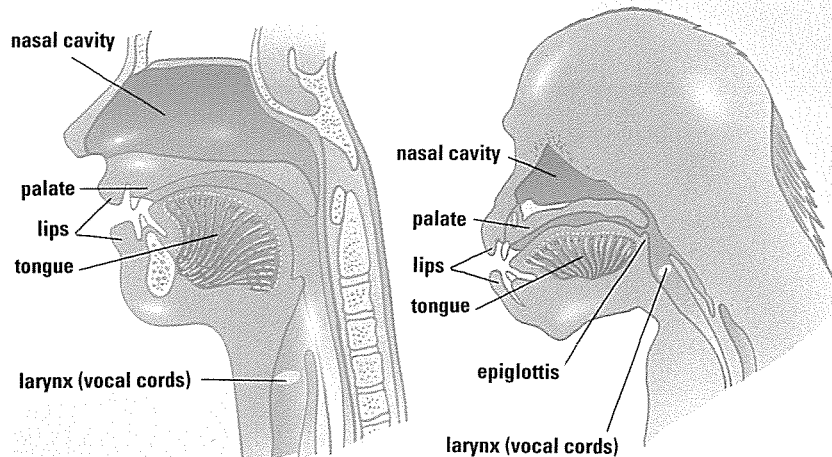
vocal cords. During ordinary breathing these are relaxed, leaving a wide space for the air to pass through.

When we speak, the vocal cords tighten and close together. As air is forced past them they vibrate, making a humming noise. Changing the tautness of the cords is instrumental in altering the pitch and tone quality of any sound we make.

Pitch variation

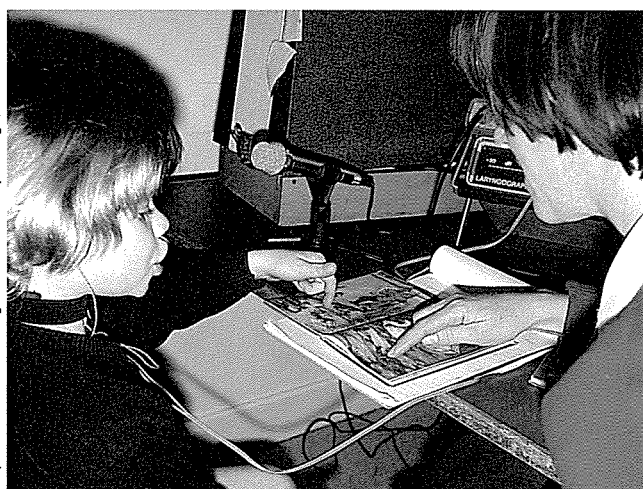
A person's larynx produces a range of different pitches. Children have a higher pitch range than women, and women's pitch range is higher than that of men. Changes in pitch are heard as changes in the intonation of the sentence. For example, by changing the pitch in the sentence 'tea tastes good', we can change the sentence from being a question to a statement. When we speak in a very

Human and Chimpanzee Vocal Equipment



Joe Lawrence

Dept of Phonetics & Linguistics/University College, London



The speech of this child, who has impaired hearing, is being recorded to monitor her development. In addition, sensors strapped on the child's throat are picking up information on the regularity of the vibration of her vocal cords.

Chimpanzees have been raised from birth with human infants in attempts to teach them to talk. But the chimps never learned more than a few words, such as 'mama'. Later, it was realized that apes could never talk like humans, even if they were able to understand our language, because their larynxes have the wrong structure.

excited voice, we tend to use a wide pitch range. If on the other hand, the pitch is kept constant, the resulting speech sounds very monotonous, like a monk intoning grace.

Harmonics

The humming noise, produced as a result of the vibration of vocal cords, is a complex sound made up of a fundamental frequency which determines the pitch we hear, and a series of harmonics, or multiples of this fundamental. The strength of each of these harmonics depends on the shape and size of the cavities in the mouth and nose and determines the vowel sound that is produced. By changing the position of our lips, jaw and tongue, we change the size of these cavities and, as a result, will produce a different vowel sound. To test these ideas, make a steady sound with your larynx. Alter the position of your lips, jaw and tongue and see what effect this has.

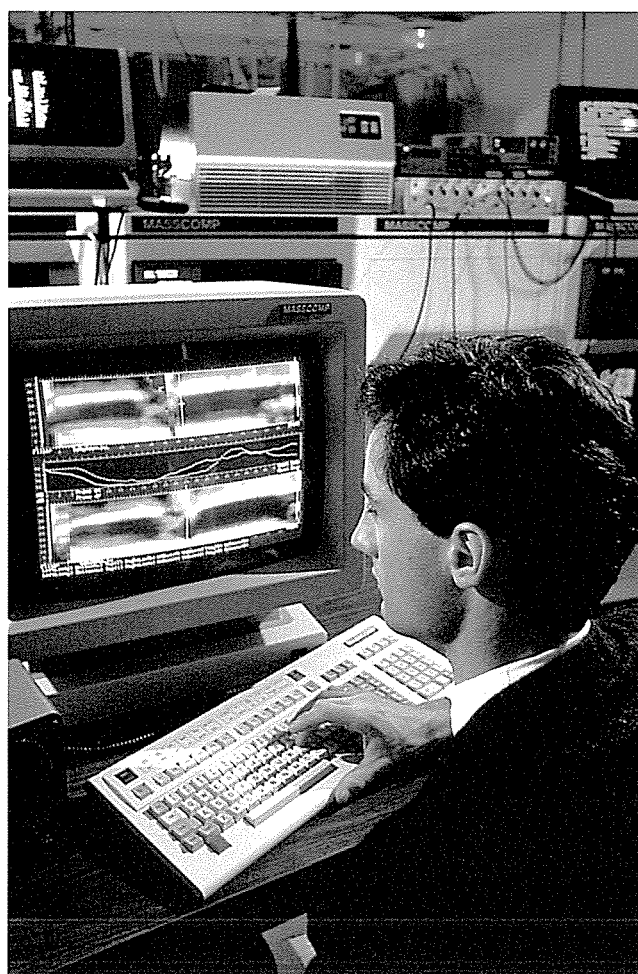
Intelligible speech

Although the larynx is the actual source of the words we speak, its actions are controlled by the brain. We first decide what is to be said, then instructions travel from the brain to control the movements of muscles around the larynx and mouth.

Two small regions of the brain, in particular, seem to be very important

PARROT-SPEAK

For over 13 years, Irene Pepperberg of Northwestern University Chicago has been training an African grey parrot named Alex to talk. He can now identify 30 different objects, six colours, five shapes and quantities up to six. He learnt 'grey', for example, by associating the word with the colour of his reflection in a mirror. His reward is usually to receive any object that he correctly identifies, which he then destroys with his powerful beak.



Hank Morgan/Science Photo Library

The word 'baby' is analysed on screen by a scientist working on the development of a computer system that recognizes human voice patterns and can communicate in natural language.

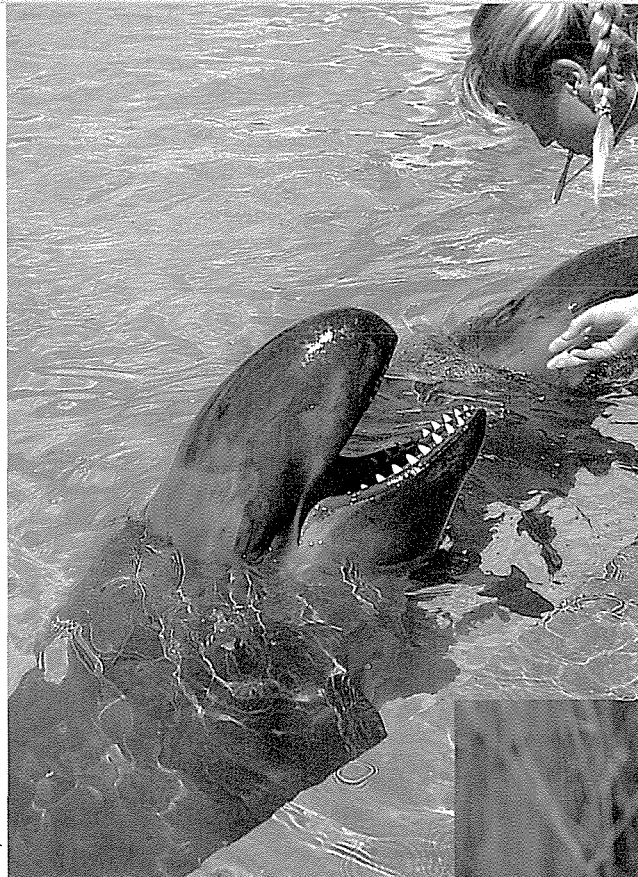


Hand signals and whistles are used to train a false killer whale.

Whales, dolphins and porpoises have a wide range of vocalizations, both within and beyond the range of human hearing. They also communicate by whistling and with 'body language' such as water-slapping and biting.

The male zebra finch (far right) lays claim to his territory by singing. He learns his call by imitating other zebra finches.

Tony Martin

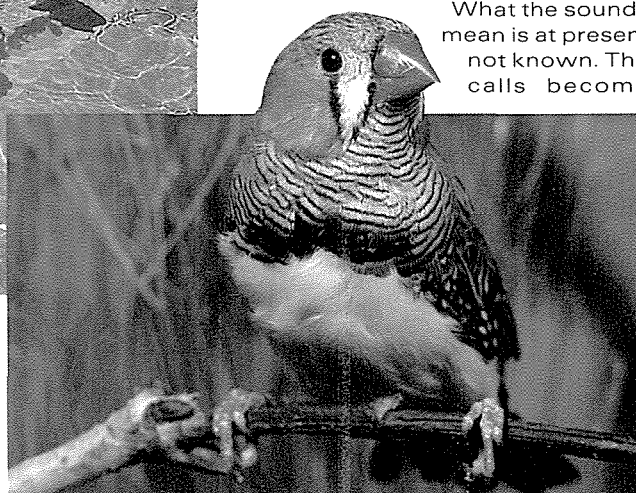


of whistles and calls used by the animals when communicating under water. These are quite distinct from the high-pitch sonar clicks that they use for navigating and finding prey.

Whistling whales

Research has shown that members of a group, or pod, of whales make 12 distinct calls. All members of the pod can and do produce all 12 calls. Usually, each pod has a unique set of calls, but sometimes the same call is found in more than one pod. These calls are passed on from one generation to the next; and whale groups that have some of the same calls probably share a common ancestor.

What the sounds mean is at present not known. The calls become



Hans Reinhard/Bruce Coleman Ltd

DID EARLY MAN TALK?

language. When Broca's area is damaged, a person's speech is affected but he or she can still understand what is said by someone else. Damage to Wernicke's area, however, leaves a person still equipped with the power to speak but unable to put words together in a meaningful way.

Amazingly, we all learn to speak a complex language, such as English, within a few years of birth. By the age of five most children have mastered the most important parts of their native language. How is this possible?

Verbal fluency

It seems that when we are born, the pathways inside our brain are only partially connected. As we hear others speak, we experiment with words and automatically learn the basic structure of our language. These rules of grammar, and the meanings of words, are then built into the brain for the rest of our lives.

Once all the pathways inside the brain have become fixed, it is much harder to learn a new language. This explains why, as adults, we may spend many years trying to master a foreign language that young children of that country can speak fluently.

Other animals also use sound to communicate with each other. Scientists have found that killer whales, for instance, 'speak' in a variety of different dialects and languages. The differences may be as small as those that separate regional dialects in the English language, or as large as those between, say, English and Japanese.

Killer whale dialects are made up

faster and of a higher pitch if the whales are excited. The most probable guess is that they help whales to identify each other and the particular pod to which they belong.

Many birds learn a particular set of songs or chirpings by imitating nearby birds of the same species. Male zebra finches, for instance, learn their song between three and nine weeks after hatching. At the beginning they just listen. Then, after 20-30 days, they start to practise their tune, perfecting it over the next few weeks.

Just amazing!

OUT OF RANGE

THE HIGHEST PITCHED SOUNDS IN THE ANIMAL KINGDOM ARE PRODUCED BY BATS. THEY EMIT A STRING OF PULSES UP TO EIGHT TIMES HIGHER THAN THE LIMIT OF HUMAN HEARING.



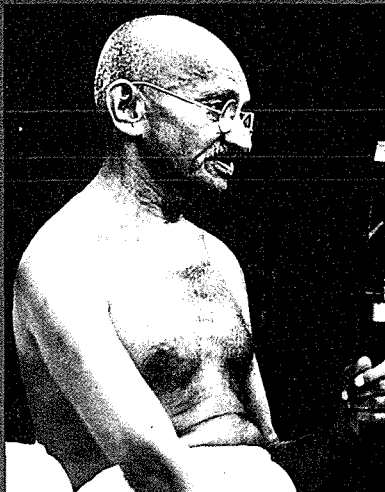
Paul Raymond



Neanderthal man was a sub-species of *Homo sapiens* who lived 100,000-35,000 years ago (see THE LIVING WORLD pages 21-24). Recently, a Neanderthal skeleton was found in Israel with an intact hyoid bone. The hyoid bone supports the base of the tongue and muscles connect it to the larynx. The Neanderthal hyoid is almost identical to that of modern man, which indicates that the larynx and tongue were also similar (although the jaw is not) and that Neanderthal man could talk. But scientists can still only guess as to whether he spoke a language.

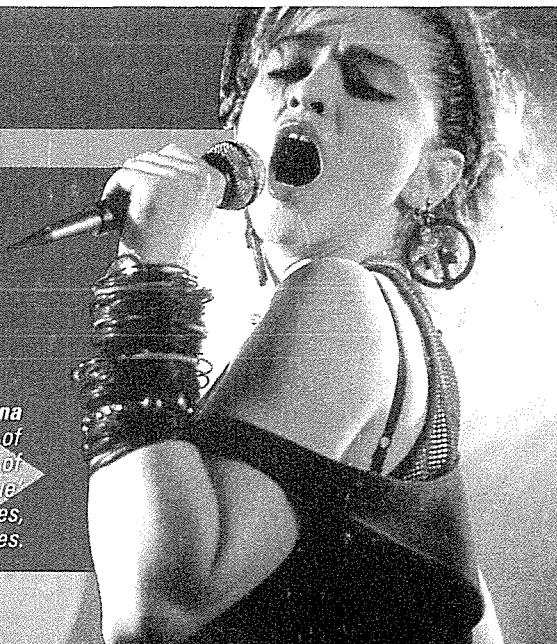
in forming human speech. These are called Broca's area and Wernicke's area. Broca's area deals with making up sentences while Wernicke's area is essential for the comprehension and formulation of spoken and written

The Huton Picture Company



Mahatma Gandhi's great message was that of Satagraha, which means non-violent resistance and truth. By promoting this philosophy he helped to free India from British imperialist control.

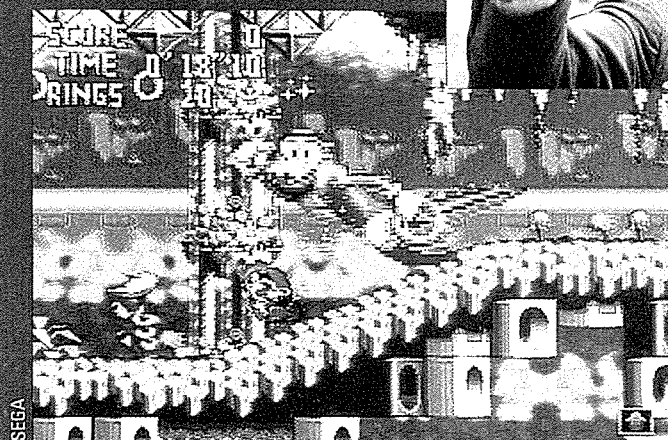
American singer, Madonna shows the power of communication regardless of language. Her album 'True Blue' was number 1 in 28 countries, selling over 11 million copies.



Gamma/Frank Spooner Pictures



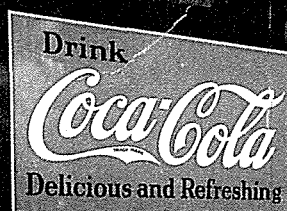
John F. Kennedy's most well remembered speech – 'Ask not what your country can do for you – ask what you can do for your country' – was included in his inaugural address on 20 January 1961.



SEGA

Animated characters used in video games, such as SEGA Chaotix, transmit a strong message to young people, often lost on adults.

Patrick Farley/Rex Features



樂可口可



Gamma/Frank Spooner Pictures

The logo for Coca Cola is universally known through the power of advertising. It is the world's most popular soft drink, sold in more than 60 countries.

The artist formerly known as Prince communicates through the media of music and film, with his androgynous image fusing black and white rhythms.

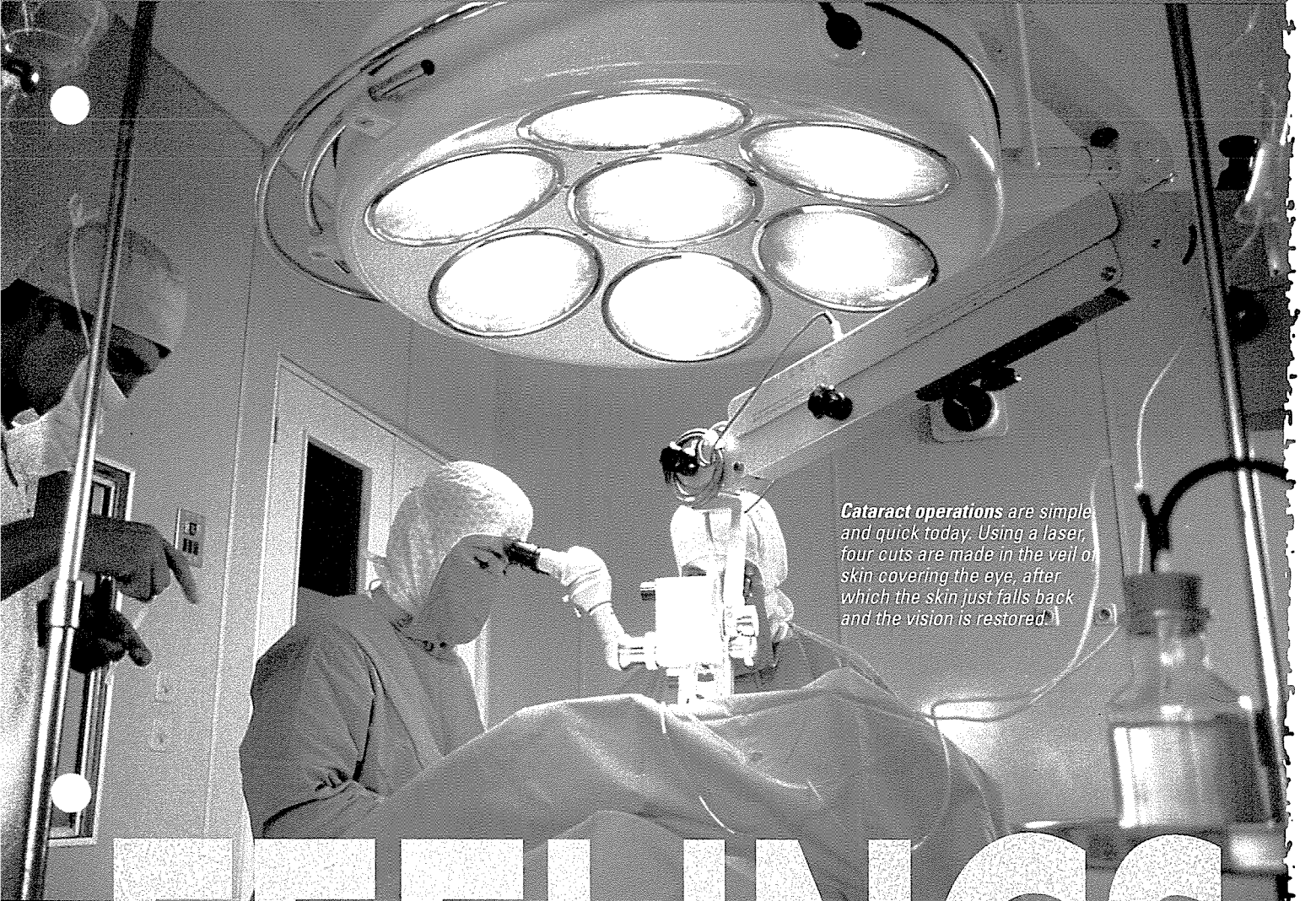
Flip Schulke/Planet Earth Pictures



Martin Luther King Jr. was leader of the civil rights movement in the 1960s. His delivery mesmerized audiences. The words on his tombstone are from one such speech – 'Free at last, free at last, thank God Almighty, I'm free at last.'

Nils Jorgensen/Rex Features





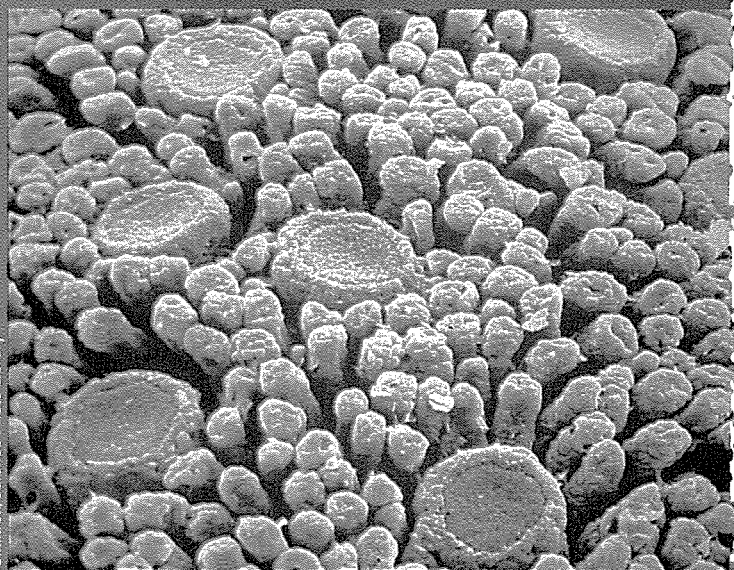
Cataract operations are simple and quick today. Using a laser, four cuts are made in the veil of skin covering the eye, after which the skin just falls back and the vision is restored.

FEELINGS

THE FIVE HUMAN SENSES ARE the brain's doorway to the world around us. By decoding the information gathered by hearing, sight, touch, taste and smell we are able to form a realistic picture of our surroundings.

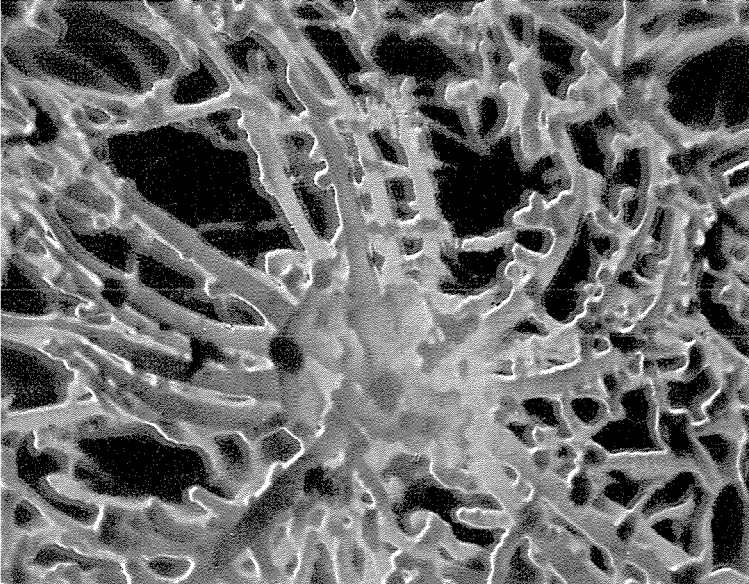
The sense of touch is recorded by receptors on the end of nerve fibres in our skin. There are six types of receptor, each of which records a separate sensation – pain, cold, heat, pressure, touch or continuous touch. They are grouped together where they are most needed. For example, pain receptors are clustered thickly on the surface of the eyes so that even pressure from a tiny piece of grit hurts a lot. Areas like the fingertips, however, have only a few pain receptors and can put up with a lot more pressure.

Papillae cover the human tongue. The smaller filiform papillae are just 2-3 mm high and contain the nerve endings for the tongue's sensation of touch. The larger circumvallate papillae contain the taste buds with which we discern the flavour of food.



Omikron/Science Photo Library



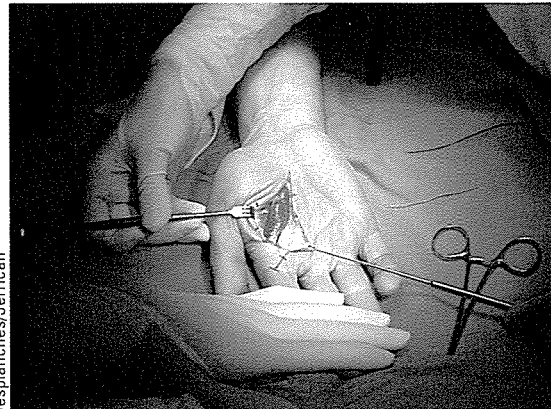


Smell receptors are found in the olfactory epithelium in the nasal cavity. Here a single olfactory vesicle has been magnified over 11,000 times.

Microsurgery enables severed nerves to be reconnected. If a hand or foot is cut off, surgeons can sew it back on and also restore the sense of touch.

particular type of receptor.

Perhaps the most important sense is sight. The eye works like a camera. Light goes in through the pupil. The amount of light that goes into the eye is controlled by the iris, which is the coloured area surrounding the pupil. The iris muscles make the pupil bigger when the light is dim, but shut it down



Desplanches/Jerrican

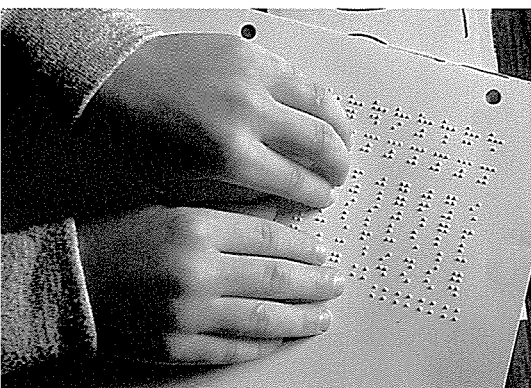
The senses of smell and taste are closely related. Food that smells good usually tastes good. Your sense of taste is governed by taste receptors on your tongue and your sense of smell by smell receptors in the cavity behind your nose.

Taste sensation

When you put food into your mouth, chemicals from the food react with the receptors to produce the sensation we call taste. Some of the chemicals float into your nasal passages and simultaneously stimulate your smell receptors.

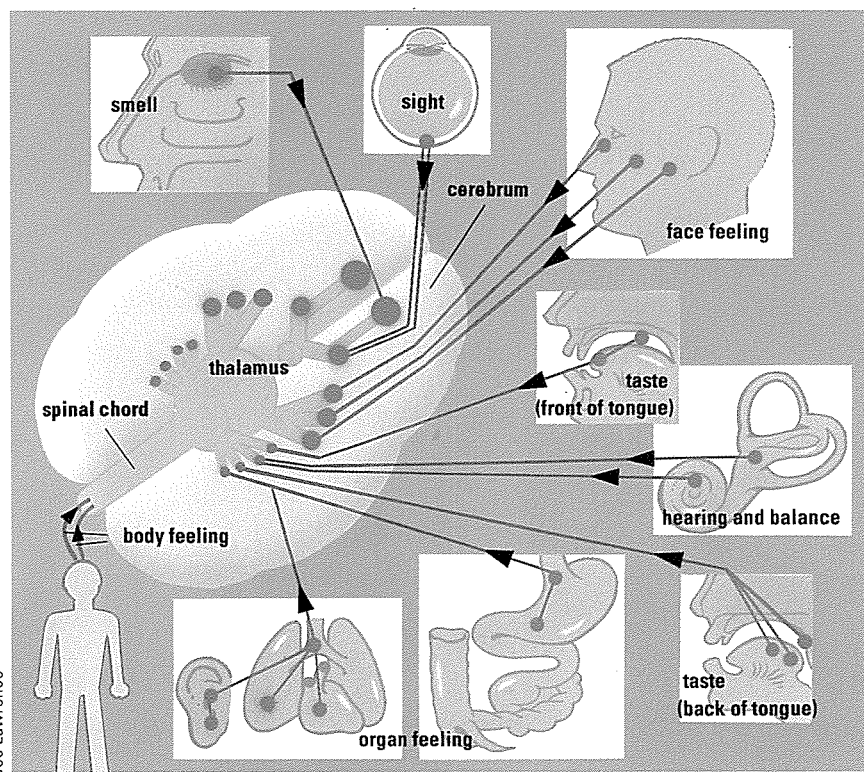
The taste receptors are called taste buds. They are grouped together on papillae, which are the little rough bumps you can see on the tongue. These taste buds are grouped together, with each group sensitive to a

Braille enables the blind to read. Each letter of the alphabet has its own pattern of raised dots which can be identified by touch. The dots, 3 mm apart, can be read at a rate of about 2,000 per minute – equivalent to 100 words.



Joe Lawrence

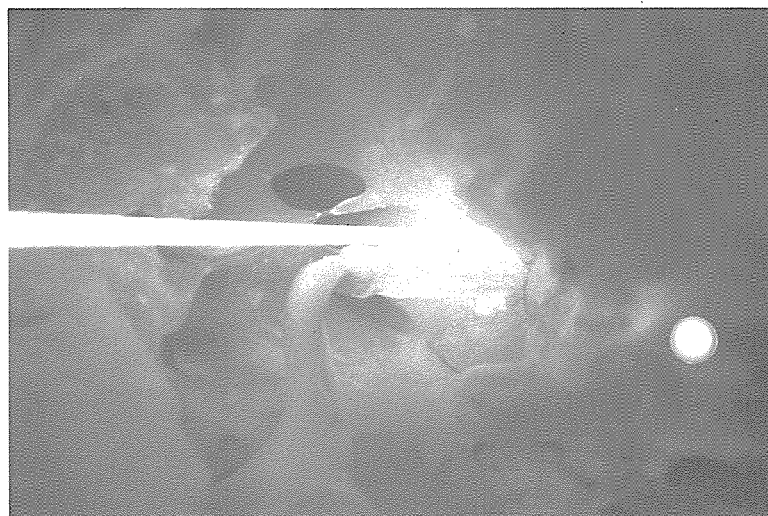
One theory is that most smells are mixtures of a few basic odours each with their own receptors – like a coded message. Each smell is made up of molecules with a distinctive shape, and each molecule slots over a



Alexander Tsiras/SPL

The brain receives sensory messages in the cerebrum, or forebrain, via the nerves and the part of the brain called the thalamus – a kind of 'preliminary impulse sorting office'.

The eardrum is extremely delicate. Argon lasers can be used to drain off fluid or make an incision in the membrane to allow surgery, thus avoiding damage.



different kind of taste. Sweet and salt tastes are 'measured' at the front of your tongue, sour tastes at the sides and bitter tastes at the back. You can try this by putting a tiny bit of a particular flavour, such as salt, on different parts of your tongue and finding out which parts of the tongue produce a stronger taste sensation.

People can recognize thousands of different smells. How do we do it?



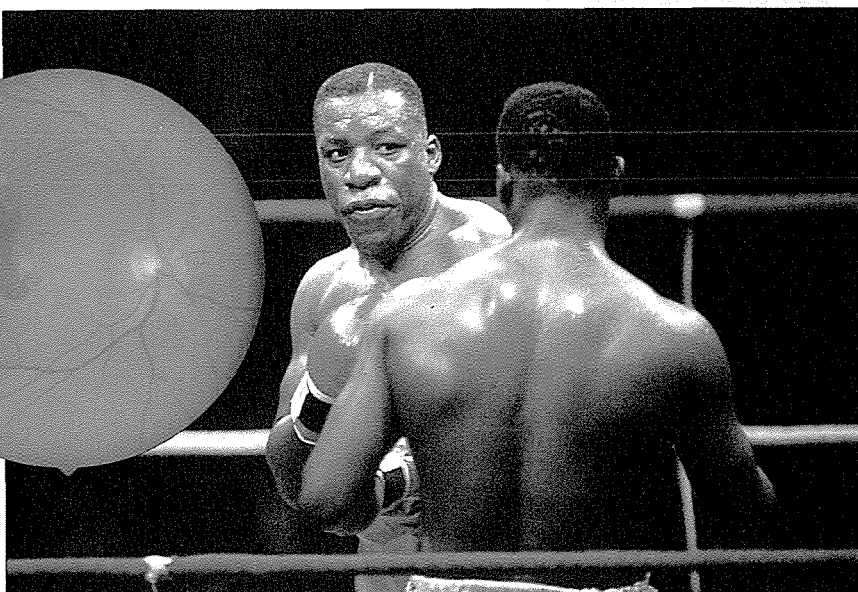
to a tiny hole in bright light conditions.

The light passes through a clear part of the eye, the lens, behind the pupil. The lens then focuses the light on to the retina at the back of the eye. Your retina is made up of two kinds of receptors. Rods respond to the intensity of the light and only see black and white. Cones respond to the wavelength of the light and see colours.

The 'picture' of the world that the lens focuses on to your retina is upside down. The brain interprets what it sees and turns everything the right way up. When the light does not focus properly on the retina, the image is blurred. If the eyeballs are a little too long, distant objects are out of focus; if on the other hand they are too short, close up objects are out of focus.

Blindness can be caused by many things. A physical injury may make the retina become detached from the nerves behind it, or a build-up of pressure of liquid in the eye can damage

SPORTING INJURIES TO THE EYES



Science Photo Library

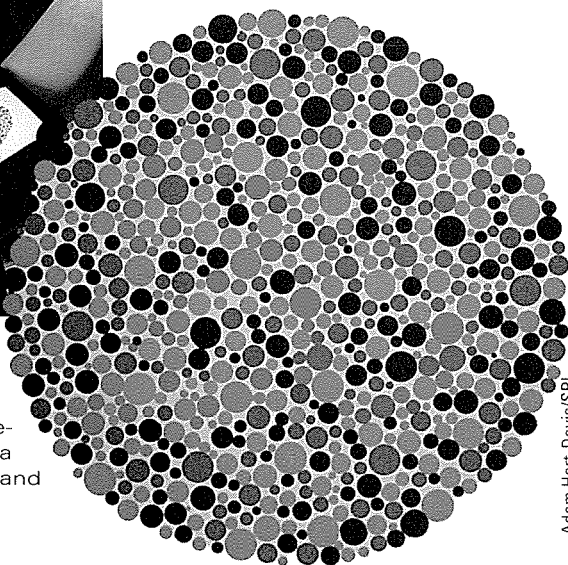
Dan Smith/Allsport

When fluid accumulates between the retina – the screen at the back of the eye – and the choroid – the layer of the eyeball it is usually connected to – the retina becomes detached and sight is lost. The separation appears as a brown discoloration (inset).

Sportsmen often suffer from de-

tached retinas. Squash has a high incidence of eye injury – not surprising considering the ball can travel at 160 km/h. Another sport in which eye injuries are common is boxing. In 1988, the British heavyweight boxer Gary Mason had to retire temporarily from the ring because of a detached retina.

Colour blindness tests detect red-green or blue-yellow deficiencies. Those with normal vision would see the number 26 (below). Those with a red-green problem would see random dots.



Adam Hart-Davis/SPL

blood vessels and receptors. These problems cannot easily be cured. But if the lens of the eye becomes opaque, forming a cataract, it can be removed and replaced by an artificial lens.

Colour blindness

Not everyone who can see can perceive all colours clearly. About ten per cent of men and one per cent of women have some defect in their colour vision. The most common form of colour blindness makes it impossible to distinguish red and green. Because colours on such things as traffic lights and industrial machinery can be vital for safety, children are now tested for colour blindness while they are still at school. It cannot be cured, but if you know you are colour

blind you can avoid certain dangers.

Hearing works in the same way as touch. Receptors convert physical pressure into electrical signals, which are sent along nerves to the brain. But the ear is more sensitive, and the brain interprets the signals differently. The signals are sound waves – vibrations which travel through the air. They are channelled into the ear where they vibrate a stretched flap of skin called the eardrum. This is connected to

three small bones, which pass on the vibrations to receptors that are deep inside the ear.

Loud noise can damage this delicate apparatus, and people who work in noisy factories or who listen to loud music a lot slowly go deaf. About one person in ten is at least slightly deaf. In those over the age of 60, the percentage is higher – one in three. The main cause of hearing deterioration with age is degeneration of the sensory (hair) cells in the cochlea and not, as often thought, any physical changes to the eardrum or middle ear. These problems can often be helped by one of the conventional hearing aids.

Just amazing!

HOT HEELS

IN 1987, A GROUP OF AMERICAN FIREWALKERS WALKED OVER COALS HEATED TO A TEMPERATURE OF 841°C – HOT ENOUGH TO MELT ALUMINIUM.



Paul Raymond

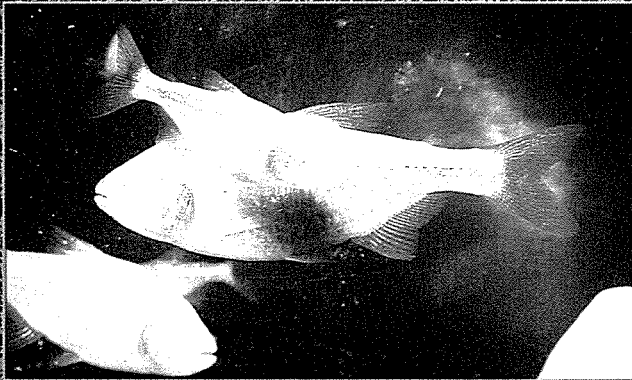


Snakes smell their surroundings by continually flicking their tongues in and out to waft scent particles to receptors located in the roof of their mouths.



D. Bremner/Tony Stone Photo Library/London

Electric eels sense their surroundings through an electric field generated by muscle cells. The field is distorted by any passing object.



Hans Reinhard/Bruce Coleman Ltd.

Sea anemones are blind animals that rely on the sense of touch. As prey brushes past its tentacles, the anemone kills it with poison.



Scott/Planet Earth Pictures



Jane Burton/Bruce Coleman Ltd.



 SLEEP DEPRIVATION

 NREM SLEEP

 INSOMNIA

SOUND ASLEEP

A THIRD OF OUR LIVES IS spent asleep, but nobody knows why. Some researchers think that during sleep your brain assimilates the information it has received during the day, and some think that sleep is the time when your body can repair itself.

Although we do not yet

know exactly why we sleep, we do know what physical changes occur during sleep. During the time that we are asleep our pulse rate and blood pressure drop. Body temperature falls and breathing slows down. Muscles relax, blood vessels in the skin become wider and our metabolic rate falls by about 20 per cent.

There are four stages of slow

wave sleep - known as non-rapid eye movement or NREM sleep, when the brain waves are slow and regular and people sometimes snore. The fifth stage is a much lighter stage of sleep called rapid eye movement or REM sleep. (Even though you are asleep your eyes dart about under closed eyelids.) An adult spends about 25 per cent of their sleeping time in REM.

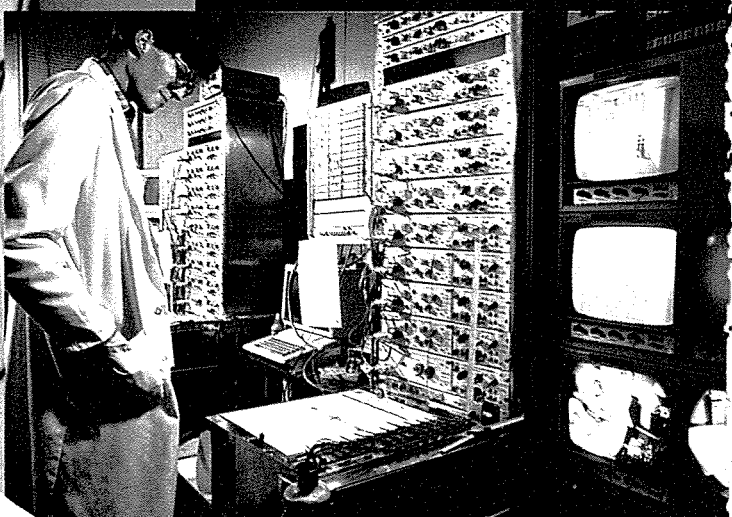
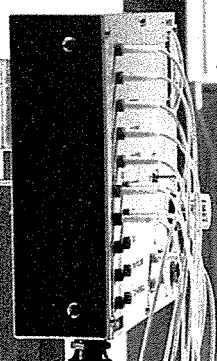
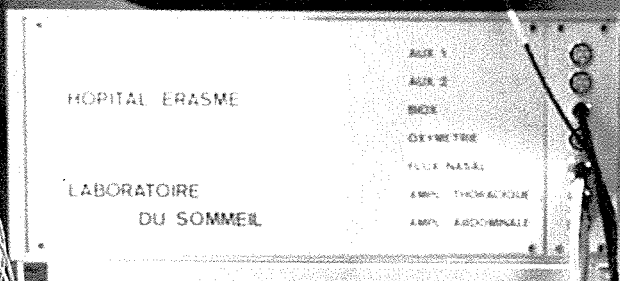
Dreams

By waking people up during REM sleep, researchers have discovered that we have our most vivid dreams during this stage of sleep. Also, everybody dreams, even though some people do not remember them when they wake up normally. The pattern of electrical activity in the brain during sleep and its relation to dreaming is now clear. But much less is known about the chemical changes involved (see BODY CHEMISTRY overleaf).

Different people need different amounts of sleep each day. Most newborn babies sleep for around 16 hours in every 24, although some

Daudier/Jarrigan

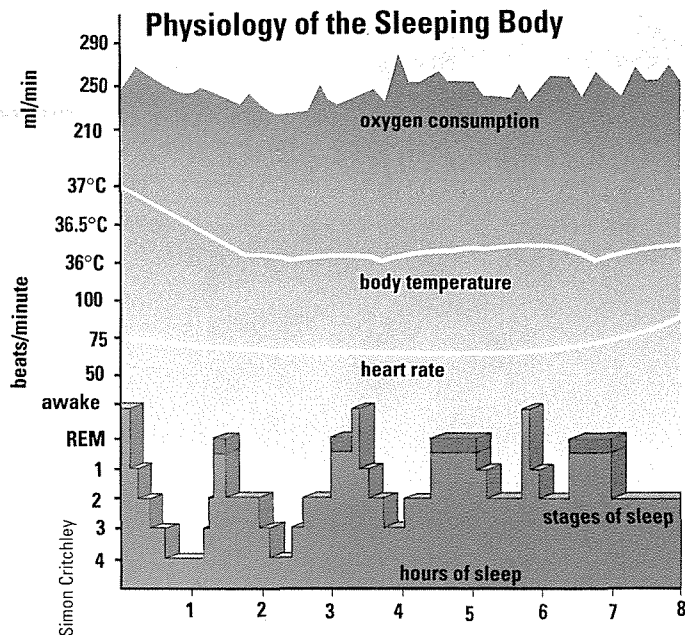
Peter Menzel/SPL



Electrodes attached to a patient's head record the electrical activity in the brain. The signals are monitored on an electroencephalograph (above).



Physiology of the Sleeping Body

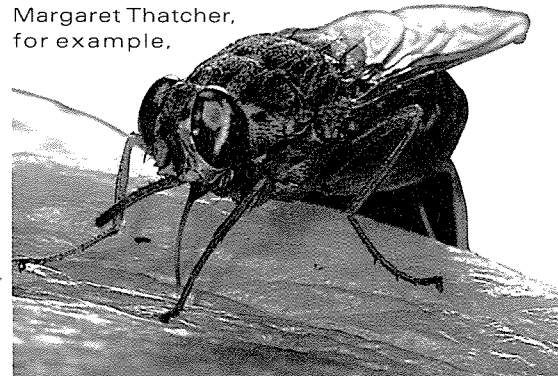


During sleep, the brain passes through five distinct patterns – four stages of successively deeper sleep known as non-rapid eye movement, and a fifth stage of rapid eye movement.

Tsetse flies spread sleeping sickness by sucking the blood of mammals, birds and reptiles. The disease can last from a few months to several years and, if untreated, can lead to coma or even death.

manage short, interesting tasks, but when they had to do long, repetitive tasks they made lots of elementary mistakes and found staying awake a desperately difficult task.

Some people stay fit and alert on a very few hours' sleep each night. Former British Prime Minister, Margaret Thatcher, for example,



sleep for as little as 8 hours in 24. Babies spend half their sleeping time in the REM stage and it may be that REM sleep is essential to make the brain develop properly. Provided that a baby is allowed to sleep naturally for as long as it wants, however, researchers have found that the amount of sleep that a baby takes has no effect on its development.

Sixteen-year-old students left to sleep and wake naturally average be-

tween 10 and 11 hours a night, and 18- to 20-year old students average 8 hours sleep a night. As people get older they need less sleep, and people aged 40 to 60 only average seven hours' sleep a night.

Researchers have not yet found anyone who can go without sleep completely. A Californian called Robert McDonald managed to stay

is said to be able to manage on only 3-4 hours' sleep in every 24.

Many people feel distressed by their inability to sleep throughout the night. Scientists at Stanford University in California, USA, found that over half of those who complained of insomnia actually stayed awake for less than half an hour a night. Their problem seemed worse than it was because time spent lying awake in a quiet, dark room seems to pass so slowly.

Kim Taylor/Bruce Coleman Ltd

BODY CHEMISTRY

Scientists have discovered minute quantities of chemicals that are thought to modify and regulate sleep. Researchers at Harvard Medical School in the USA extracted 7 millionths of a gram of a chemical called Factor S from 3,000 litres of urine. When a dose of this was given to a rabbit, it spent up to six hours in the deeper NREM stages of sleep – much longer than normal. A similar chemical is *delta sleep inducing peptide* (DSIP) which rapidly induces NREM sleep in animals and increases the amount of REM sleep. Scientists have tested a synthetic form of DSIP on humans but it was not as effective.

Petit Format/Nestle/Science Photo Library



A full-term foetus goes through stages of 'quiet sleep', during which it does not react to light noises and 'active sleep', when it is unresponsive to stimuli but has rapid eye movements.

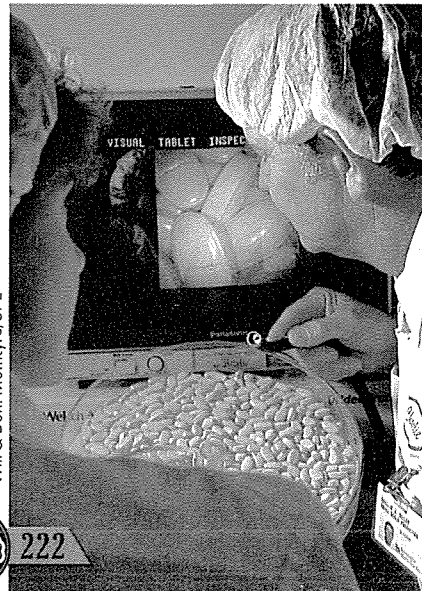
awake during a rocking chair marathon for 18 days, 21 hours and 40 minutes. But, as it is possible for humans to take catnaps with their eyes open without them realizing that they are napping, no-one is certain exactly how long Robert McDonald was totally awake during his ordeal.

Hallucinations

People who have deliberately kept themselves awake for several days have suffered blurred vision, slurred speech and hallucinations.

Student volunteers who were deprived of sleep found that after three or four days' wakefulness they could

Sleeping pills (hypnotics), such as nitrazepan, are usually prescribed for no longer than three to four weeks to reduce the risk of dependency.

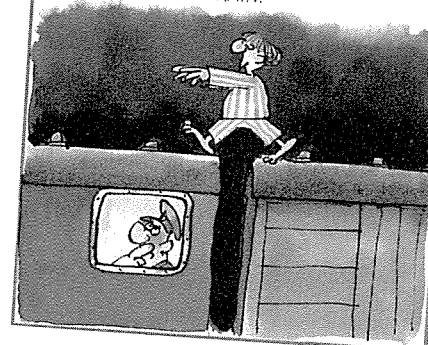


Will & Deni McIntyre/SPL

Just amazing!

THE BIG SLEEP

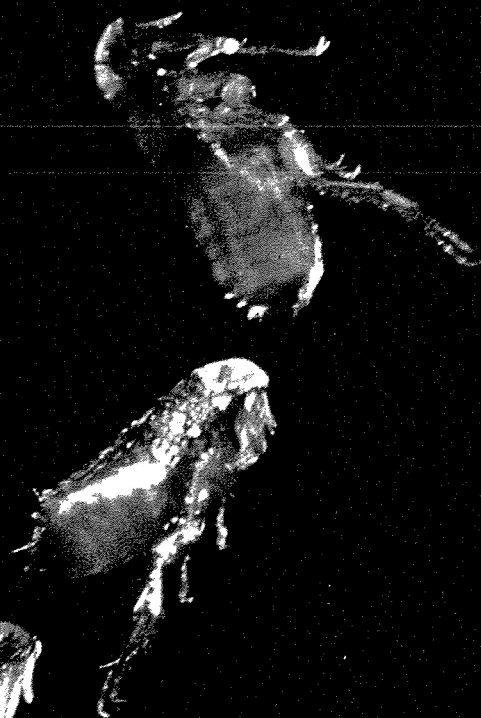
NINE-YEAR-OLD MICHAEL DIXON WAS FOUND WANDERING BAREFOOT 160 KM FROM HIS HOME IN INDIANA, USA. HE HAD SLEEPWALKED OUT OF HIS HOUSE AND BOARDED A TRAIN!



Paul Raymond



MOVE IT



A cat flea must jump on to a host, because it has no wings. Highly developed hind legs power jumps up to 30 cm into the air – perhaps 200 times its body length.

ALL ANIMALS MUST EAT to survive. Some remain in one place and allow food to come to them. But most have developed a way of getting about so that they can search for food (and avoid being eaten themselves). Methods of locomotion range from the creeping to running to the case of cephalopods, jet propulsion.

The first organisms to appear on Earth were single-celled animals and

plants. Many of them soon developed the ability to move. An amoeba, for example, creeps along by a sort of flowing motion. The material inside the cell, known generally as the cytoplasm, consists of a grainy, fluid endoplasm in the middle, surrounded by a clear jelly-like ectoplasm.

As the amoeba starts to move, a small region of ectoplasm becomes liquid and an extension, known as pseudopodium ('false foot'), starts to form. Endoplasm begins to stream up the centre of the animal, filling the

pseudopodium and pushing it forward. Ectoplasm at the 'rear' is 'used up', but more ectoplasm is created at the 'front', with the result that the whole animal moves forward. Scientists are not certain what causes the endoplasm to stream in this way, but it may be that the rear end of the amoeba contracts and squeezes the endoplasm forward.

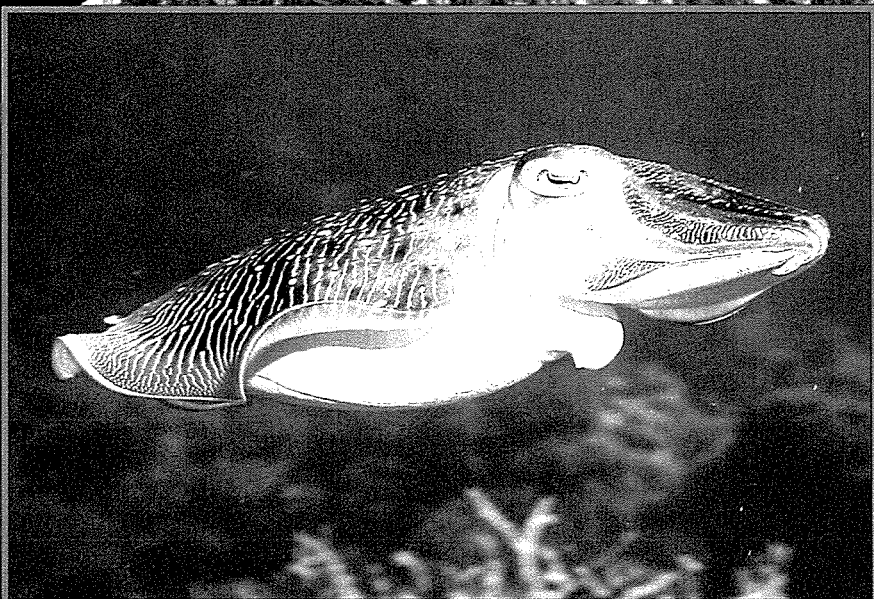
Q Gliding along

Many belted animals, without skeletons, either stay in one place or move about very slowly. A flatworm, for example, glides along on its underside using hair-like organs called cilia. It also has muscles, which produce a series of ripples that pass from the rear to the front of the body. These ripples push against the surface underneath and drive the animal forwards. A snail or slug moves along in a similar way.

Q Push and pull

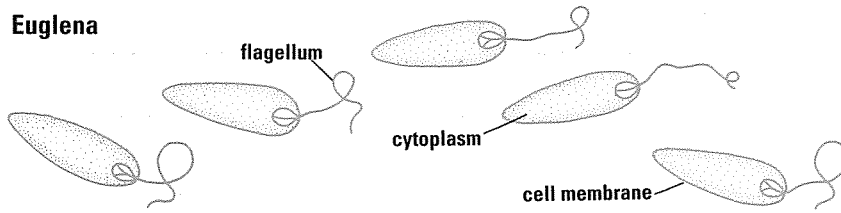
An earthworm, on the other hand, has a more sophisticated method of locomotion. Its body, like those of all annelid (segmented) worms, is divided into a series of segments, each of which is equipped with two sets of

A cuttlefish swims in the Pacific Ocean by gently undulating its lateral fins. Waves passing down these wing-like membranes drive the body forward.

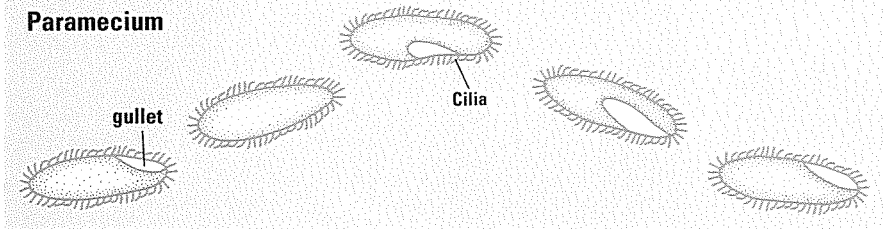


Movement by Single-celled Animals

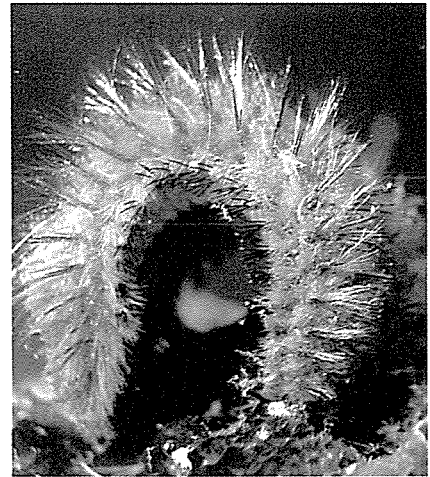
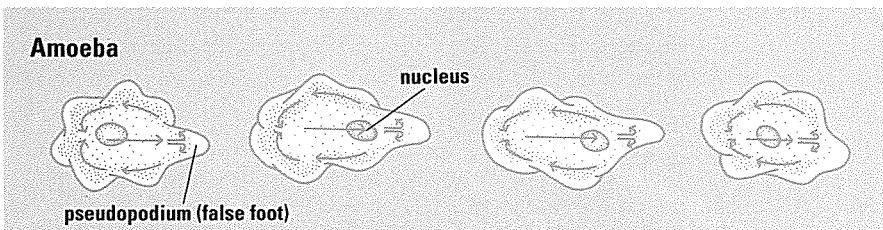
Euglena



Paramecium



Amoeba



F Sauer/Bruce Coleman Ltd

The sea mouse moves along the ocean floor on spiny projections called parapodia. It has one pair on each segment of its body.

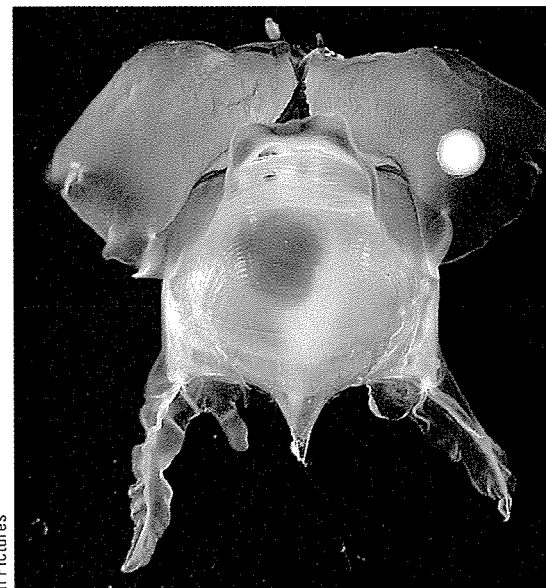
soil and those behind to be drawn up and shortened in their turn. The worm thus drives itself through the soil by causing waves of contraction to pass down its body.

Animals that live in water find it easier to get about than land animals.

A spiralling motion of the flagellum is used by the euglena to 'bore' through water. Each cilium or 'hair' on a paramecium beats just before the one in front, causing the animal to spin as it swims. An amoeba advances by extending a 'false foot' and then filling it with cytoplasm.

muscles. One set runs around the segment and causes the segment to become longer and thinner when the muscles contract. The other set runs along the segment and their contraction causes the segment to become shorter and fatter.

An earthworm moves by causing each segment to shorten in turns, starting with the segments in front to be extended and pushed through the

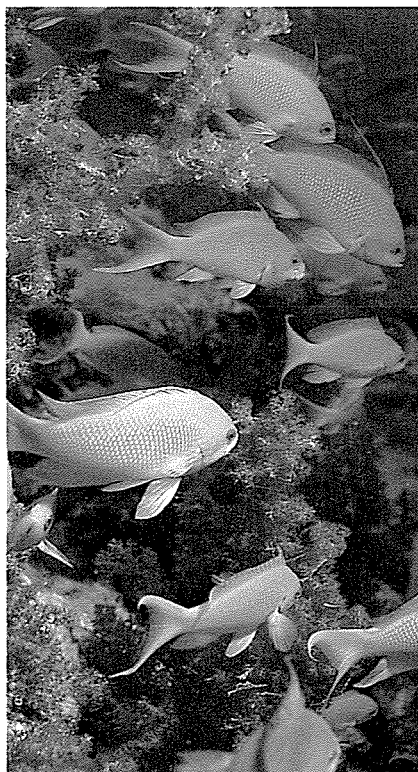


The sea butterfly swims by flapping wings that evolved from the foot on which related molluscs creep along the sea-bed.

Water, a relatively dense material, supports objects more readily than air. Those that remain on the bottom benefit by not having to support their weight on strong legs. Others succeed in getting off the bottom and propel themselves through the water.

Tube feet

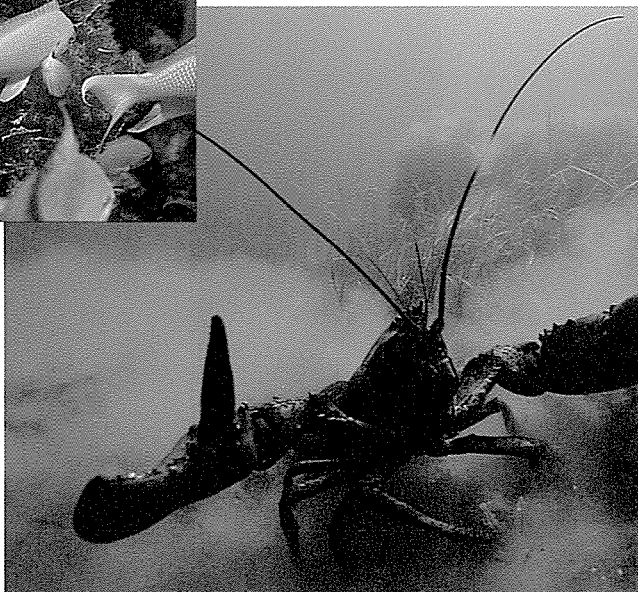
Echinoderms - 'spiny-skinned animals' - are all bottom-dwellers. A starfish moves about by using its tube feet - tiny fluid-filled tubes arranged in two rows along each of the animal's five arms. A sea cucumber also uses



P Scoones/Planet Earth Pictures

Goldfish in the Red Sea. Bony fish such as these propel themselves forward by beating their tails from side to side.

A lobster has ten legs. Its powerful pincer claws are used for catching and crushing prey rather than walking.



G van Ryckevorsel/Planet Earth Pictures

P David/Planet Earth Pictures



tube feet for locomotion. Sea urchins, on the other hand, walk slowly on their long, movable spines.

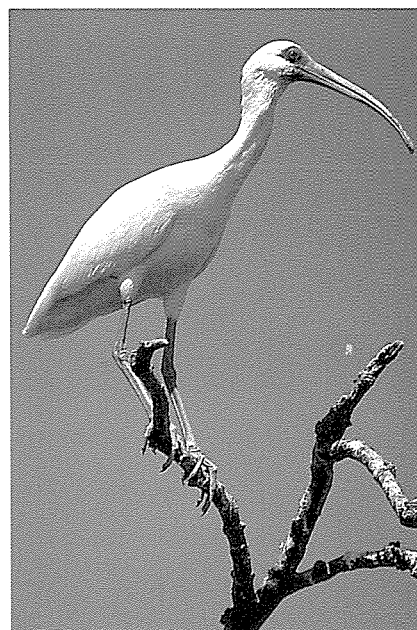
Swimming animals are to be found in most animal groups. Swimming molluscs, for example, include the scallop, which swims by opening and then rapidly closing the two halves of its shell. Some bivalves, such as cockles and razor shells, have large, tongue-like muscular feet that they use for burrowing into sand or mud. In

through a thick funnel. As a result the animal is propelled backwards. Cephalopods use this jet propulsion to escape from predators.

Swimming is usually associated with fish and it is these creatures that are supremely adapted for life in water. As a fish swims, waves of contraction pass down the sides of its body. This throws the body itself into waves and in some fish, such as sharks, these waves push against the water, helping to drive the fish forward. However, most of the propulsion, particularly in bony fish, comes from the tail as it beats from side to side.

A bony fish's pectoral ('shoulder') fins are used for steering and braking. It can float anywhere in the water because inside its body there is a gas-filled bag, or swim bladder, which is used to adjust the fish's buoyancy.

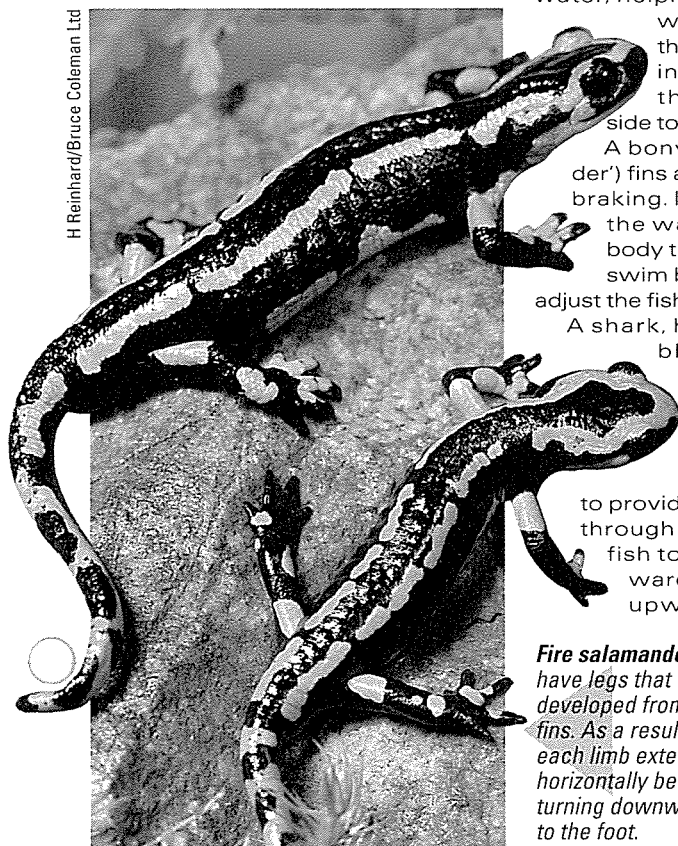
A shark, however, has no swim bladder. It must keep swimming in order to prevent itself sinking to the bottom. The head and pectoral fins are shaped like an aerofoil to provide lift as the shark moves through the water. To allow the fish to swim horizontally forward, this lift is offset by an upward force produced at



The feet of the white ibis (found in Central America) have, over many generations, become highly adapted to perching.

the tail, in which the lower lobe is larger than the upper one.

Locomotion on land is made considerably easier by the use of legs. However, the only invertebrate animals that have legs are the arthro-



Fire salamanders have legs that developed from fins. As a result, each limb extends horizontally before turning downwards to the foot.

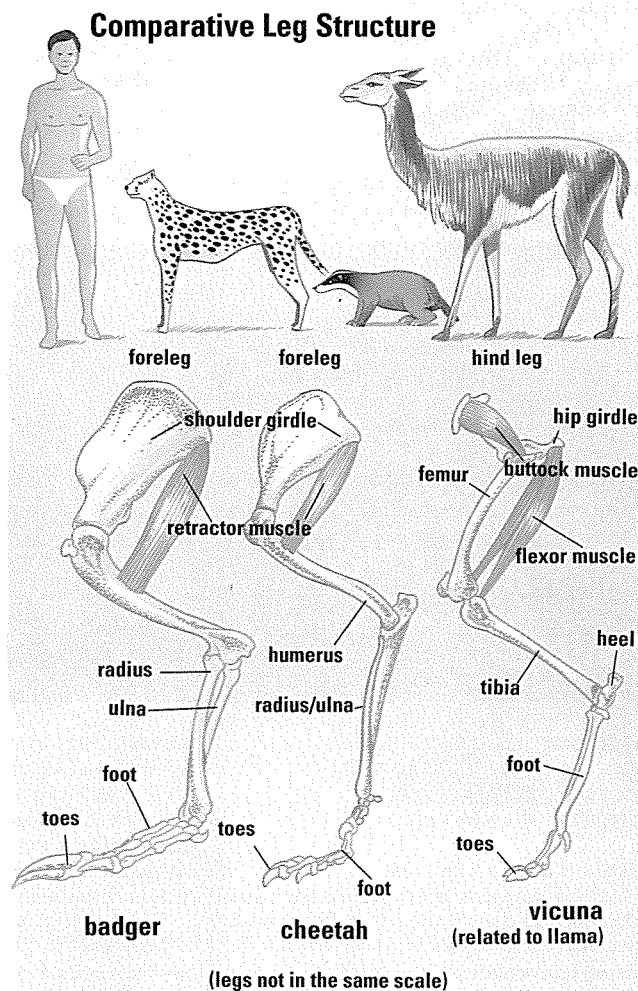
cephalopods such as octopuses, the foot is divided into a number of tentacles that surround the head.

Squirting water

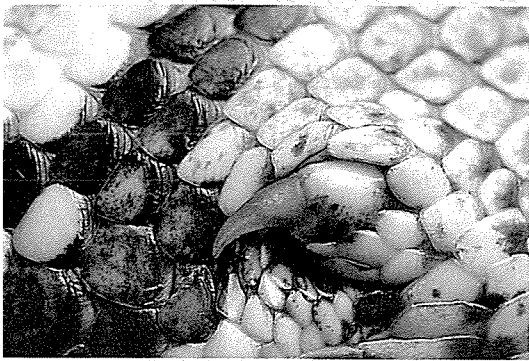
Octopuses, squid, cuttlefish and nautilus – all cephalopods – also have a way of moving more rapidly. Part of a cephalopod's body is formed by a thick membrane known as the mantle, inside which is a cavity. The cavity can be filled with water, which can then be expelled very rapidly

The speed at which a mammal can run is affected by how the feet and toes are placed on the ground. Whereas a badger has its whole foot on the ground, a cheetah walks and runs on its toes and a vicuna on the very tips of its toes.

The kangaroo uses its powerful hind legs to progress in a series of long bounds up to 8 metres in length. Grey kangaroos can be as heavy as 90 kg and over 1.8 metres tall.



LEGLESS SNAKES



One group of reptiles, the snakes, have dispensed with legs altogether. Their ancestors are thought to have been a group of lizards that took to burrowing in the ground and gradually lost their legs. Some snakes, such as the python, still have tiny, vestigial legs (see above). Today most snakes get about by throwing their bodies into a series of backward-moving waves that push against objects on the ground. Alternatively, some snakes use the edges of their ribs and their belly scales to drag themselves slowly along. Sand is a particularly difficult surface to grip and sidewinding snakes solve this problem by moving in a series of sideways steps.

A Bannister/NHPA

pod (a name that means 'jointed limb'). This group appears to have evolved from segmented worms. The most primitive types, such as centipedes and millipedes, have a pair of legs on each segment. As a centipede or millipede walks, each leg moves just after the one in front of it; waves of leg movement thus pass down each side of the body. But only a few of the legs are actually touching the

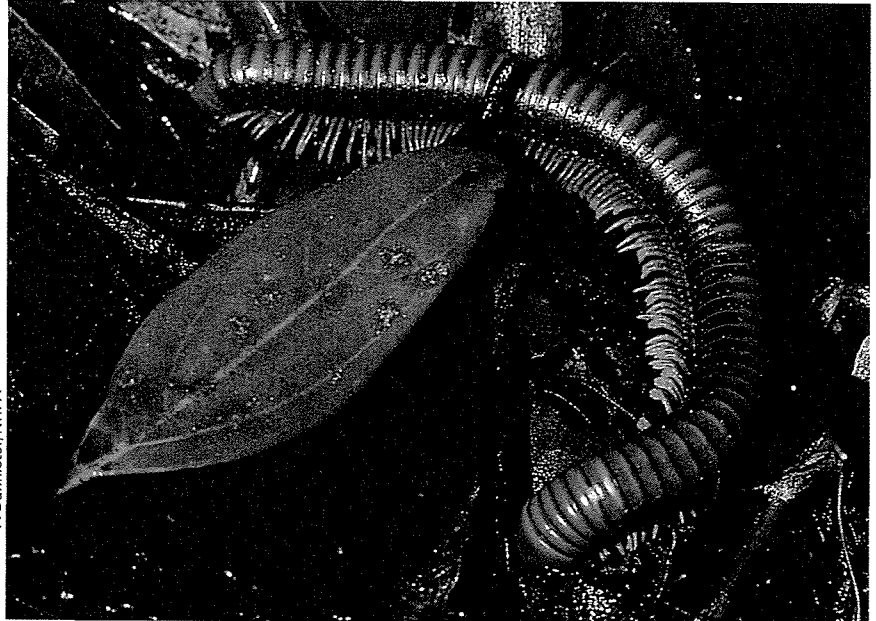
Arachnids – spiders, scorpions and their relatives – have eight walking legs. Insects have six. Having fewer legs enables them to move about more quickly, but an animal with a hard outer skeleton must have a minimum of six legs if it is to remain stable while moving around, so at least three legs touch the ground at any moment.

Land vertebrates typically walk on four legs. Amphibians were the first to evolve. They arose from a group of fishes that had two pairs of lobed fins.

because the force is exerted along the length of the legs, they can be much thinner than the legs of a reptile. Birds walk on just two legs that extend downwards; their forelimbs have become wings used for flight.

Running and jumping

These factors help mammals and birds to move more quickly than reptiles. Mammals and birds also have more highly developed balance systems. A mammal moving slowly lifts



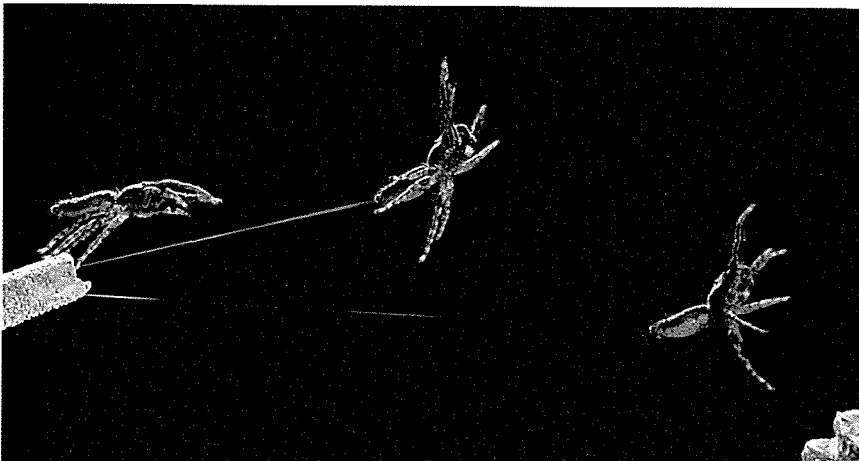
B Parsley/Tony Stone Photo Library, London

As with all fish fins, these were on the sides of the body, which is why a typical amphibian, such as a salamander, has limbs that are held out sideways.

Much the same arrangement is found in reptiles. The upper part of each limb is held out horizontally, and the lower part then extends down-

A millipede has up to 200 legs. It appears to have two pairs of legs to each segment of its body, but each 'segment' is in fact two segments fused together.

only one leg at a time off the ground. As it increases its speed, two, three or even all four legs may leave the ground at the same time. All limbs also leave the ground when a mammal jumps but this skill is more highly developed in frogs and toads and insects such as grasshoppers and fleas.



K Taylor/Bruce Coleman Ltd

A jumping spider in mid-leap. It runs along the ground on eight jointed legs, stalking and pouncing on unwary prey.

ground at any one time.

Crustaceans also typically have pairs of legs on most of their segments, but in many cases not all are used for walking. A woodlouse uses only seven limbs for this purpose.

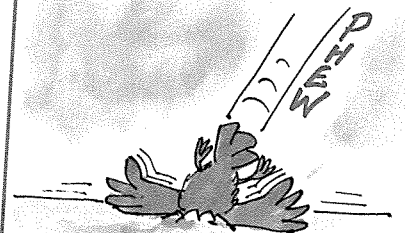
wards to the foot. This arrangement is wasteful of energy as a great deal of effort has to go into lifting the body clear of the ground. In many reptiles, particularly the larger and heavier ones, the body rests on the ground for most of the time.

A mammal's legs extend downwards directly underneath the body – like the legs of a table. Very little effort is therefore needed for support and

Just amazing!

EXHAUSTING

TO STAY IN THE AIR, SOME HUMMINGBIRDS HAVE TO BEAT THEIR WINGS 60–70 TIMES EVERY SECOND. TO RECOVER, THEY MUST SPEND 12 HOURS OF EVERY DAY ASLEEP.



Paul Raymond



COMMUNICATION BETWEEN humans consists of thousands of sounds, which we combine to produce the words that fill huge dictionaries. Our language sounds are very different from one country to another – straightforward English compared with sing-song Chinese, or the staccato clicks of Kalahari bushmen, which no European vocal cords could produce, sounding more like a burst of machine-gun fire.

Then there is our music, in all its varieties, orchestral and solo: classical, rock, modern, jazz and the kaleidoscope of sounds that we call pop music. So are we the experts of the animal kingdom in speech or musical communication? Far from it. The huge variety of birds' songs and calls are not just attractive musical features of the countryside, they are just as varied, purposeful and important as our speech.

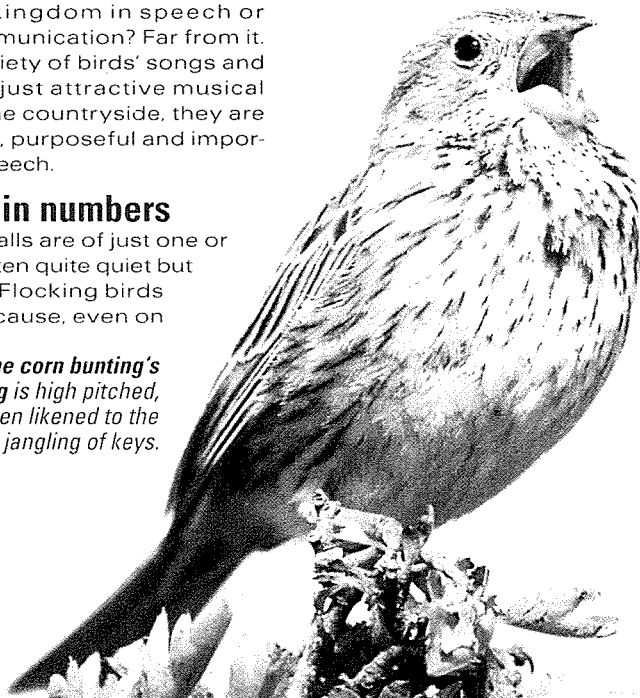
Roger Wilmschurst/RSPB



Safety in numbers

Simple bird calls are of just one or two notes, often quite quiet but penetrating. Flocking birds use these because, even on

The corn bunting's song is high pitched, often likened to the jangling of keys.



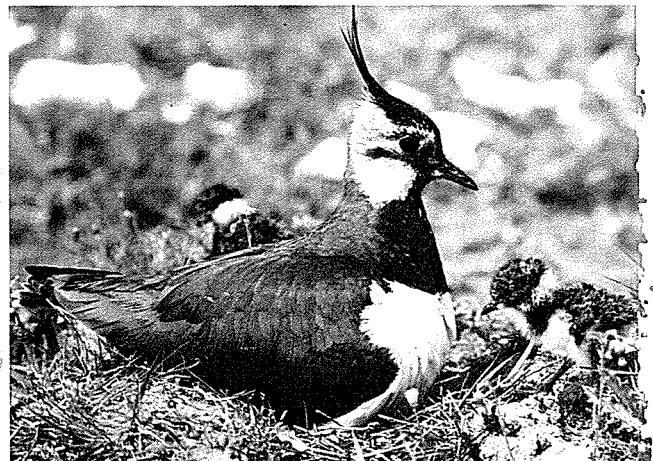
the ground in a stubble field, others of the flock are well camouflaged and out of sight. Birds like finches and buntings find extra safety from birds of prey in flocks, and many pairs of eyes also make food-finding easier, especially in midwinter when days are short, nights long and food scarce. Staying together, being a member of the pack, could make the difference between life and death.



Staying in touch

In dense forests, loud harsh calls travel long distances through the leaves. Forest birds as colourful as South American scarlet macaws, large long-tailed parrots, or acorn-gathering jays in Europe, keep in touch with their life-long mates in this way, because visual contact is difficult to maintain.

The male lapwing has a distinctive 'display call' in the breeding season accompanied by a striking aerobatic display.



Roger Wilmschurst/Bruce Coleman Ltd

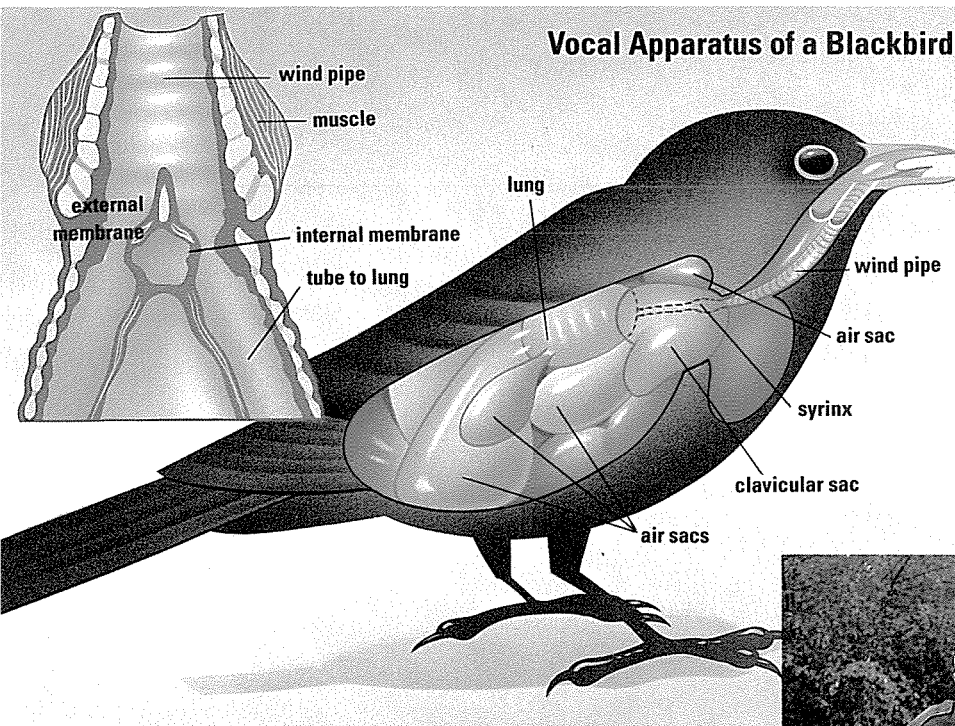


Vocal Apparatus of a Blackbird

Joe Lawrence
obeyed by the chicks. If not, further warning calls, getting increasingly loud and shrill, order the young to remain silent and still.

Static camouflage

Young lapwings, scampering about the marshes feeding, although only a few days old, are always under the watchful eyes of a parent. The parent keeps in touch with its brood by sight, using the chick's striking white neck patch as a marker. If a crow approaches, at a shrill warning from the adult the young will crouch, pressed close to the earth. Head down, the white nape is invisible and their speckled down gives almost perfect camouflage against the grass. The parents keep up their alarm calls, and the young stay motionless, even if the



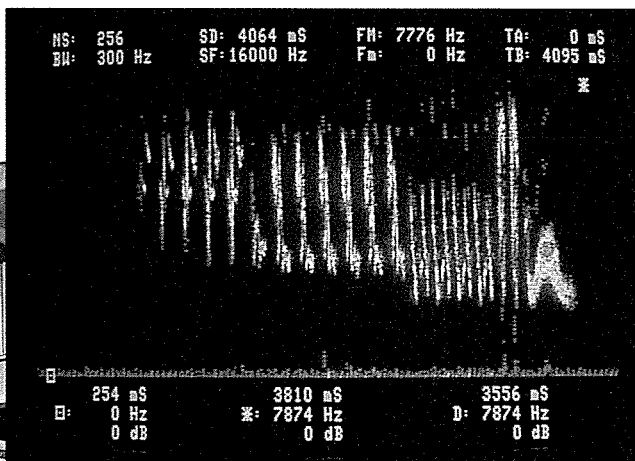
Maintaining continuous contact could make the difference between life and death for many migrant thrushes. Each spring and autumn, flocks of them travel thousands of kilometres, flying in overnight stages, feeding during the day. For novices in the flock, experienced older birds provide valuable leadership and

The sound producing organ of birds is called a syrinx (inset). The clavicular air sac is essential for sound production – if punctured the bird becomes mute.



© British Library National Sound Archive

A sonogram plots frequency against time to provide a permanent visual image of bird song.



Recording of bird song played at a slower speed shows that what appears to us as a single note is a sequence of separate sounds.

crow comes within a few centimetres. In this way they usually manage to escape, as crows' eyes are best at detecting movement.

All of these simple contact or warning calls are specific, only understood by birds of the same species, although as parental alarm calls rise up the decibel scale, it is difficult to believe that other birds take no notice. Certainly, if the worst happens and a chick is caught or if a sparrowhawk catches an adult starling from a flock, the victim's shrieks of distress make certain that all other birds know about the danger and either hide or flee.

Summer serenade

Full song is usually a feature of spring and summer. It starts as the days begin to lengthen and birds begin to think about display, establishing a territory and finding a mate. Often there are peak periods of song production: the 'dawn chorus' is a well known and much enjoyed feature, except where the 'singers' are herring gulls, producing their raucous laughing 'song' from the rooftops of seaside holiday hotels, the volume waking the guests in the early hours of the morning. Birds probably sing at dawn because it is only when insect

Sonograms are the international language for bird sounds and allow laboratory analysis in ornithological studies without access to the actual recording.

navigation. In darkness, the best way for flock members to keep in touch is by calling at frequent intervals, using simple high-pitched calls that are more clearly audible at considerable distances through the quiet night air.

Danger alert

Parent birds guarding their young, warning them of approaching predators like cats or magpies, also use short simple calls. First warnings are subdued, and are usually instantly

© British Library National Sound Archive

© British Library National Sound Archive



The song of the chaffinch has been extensively researched. The findings indicate that young birds separated from other chaffinches have a song of the right length and the right number of notes but these notes are incorrectly phrased. The scarlet macaw (far right) has an ear-splitting shriek.



Eric & David Hosking



K Wothe/Bruce Coleman Ltd

food has not begun to move around and plant food is covered in dew that birds have time to sing. But it is a measure of the importance of bird song that they will sing, sometimes on and off for a couple of hours, even though they must be hungry after the night. Almost as much a feature is the 'dusk chorus'. In the evening, after a good day's feeding, it is easier to under-

stand that a useful singing time occurs as the light fades and food is increasingly difficult to spot.

But what is singing for – certainly not just so that we can admire the beauty of a nightingale's flute-and-cello-like phrases, or relish the blackbird's melodious warbling even in the heart of our busiest cities. It is thought that it serves two main important

SUPERSENSES

The hearing of owls is highly developed. Though there is no outward sign, behind the fluffy feathers of the owl's rounded head are two huge ears. Each takes up about 15 per cent of the skull surface, and the ears are in a different position on each side of the head – one lower down and nearer the 'chin', the other higher, and nearer the back of the head. (Shown below with feathers removed to indicate position.) This asymmetry allows owls to judge exactly where a sound is coming from. The disc of stiff feathers that gives owls their characteristic 'face' works like the parabolic reflector used by sound recordists gathering faint sound waves and focussing them on the ears. In total darkness in a laboratory, where an owl's eyesight is useless, long-eared owls have pinpointed mouse prey at 30 metres.

Joe Lawrance



A saw whet owl capturing its prey. Its hearing apparatus can locate sound on two planes giving it the ability to form a sound map. Its call is a mellow whistle.

sure that everyone knows where everyone else's border is. Sometimes, as in human life, there are border disputes, and slices of territory are lost and won, usually after vocal battles

functions, both connected with the breeding season. One is to tell others of its own species where the boundaries of its territory lie. Some birds will be able to nest and raise their young largely within the boundaries of their territory – or 'living area' – and this includes most true songbirds. Other birds, like terns which live in close-packed colonies, have territories little bigger than a dinner plate, and little or nothing in the way of song.

Border patrol

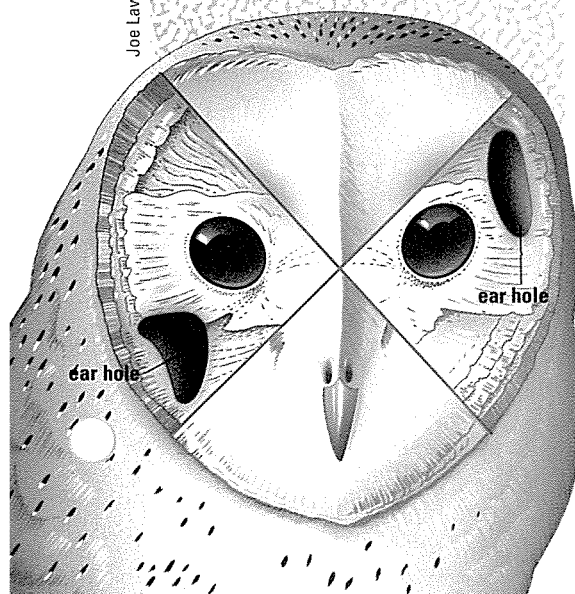
So songbirds, usually only the male, regularly patrol the boundary of their territory, pausing at a number of prominent perches or song posts to produce a burst of song to make

and much posing, less often with actual fighting. Not all birds have suitable singing perches in their territory. Those that live in open country, moors and downland and grassy plains, like larks, have developed the ability to hover, often bouncing up and down like a yo-yo, 50 or 100 metres above the ground, singing all the time. They do this at intervals around the margin of their territory.

Aural attraction

The other major purpose is to attract a mate. It is usually the male that does the singing, and there is evidence that the better developed and more elaborate his song, the quicker he will find, and the easier he will keep, a mate.

R Austing/Frank Lane Picture Agency





The wide open spaces of airfields appear safe, and are popular habitats for flocking birds that range in size from starlings to gulls. Birds, however, constitute a serious flight hazard to aircraft, especially during the most dangerous periods of flight – take-off and landing. Even one starling is capable of damaging an expensive jet engine beyond repair, and a collision between a flock of gulls and a passenger plane on one occasion caused the plane to crash with loss of human life.



Aviation Picture Library

BIRD SCARING

Recordings of bird distress calls, usually more effective if considerably but accurately amplified, are often used to scare birds away from runways. Distress calls are produced by catching a bird and holding it upside down. Often tapes are played from a travelling Land Rover, but distress calls must not be broadcast too frequently, or birds will see through the scare tactics and take no notice. Sometimes powerful fireworks, imitating gunfire, are used to give extra scaring effects.

Young males hatch able to produce the basic rudiments of their song instinctively. By listening to others, and adding copied phrases sometimes of their own kind, sometimes mimicked from other species, they gradually develop a better, richer song that helps them become more successful.

and pour out their jangling song, wide open beak pointing towards the sky and head turning slowly from side to side to give maximum coverage. Far overhead, females hear these songs and descend to find a mate.

Because they depend so much on calls and song, birds must have good hearing. Researchers estimate that birds hear eight or ten times better than we do. You can check out the coded messages within

likely that these messages are broadcast repeatedly, rather like we use public information tape-recordings.

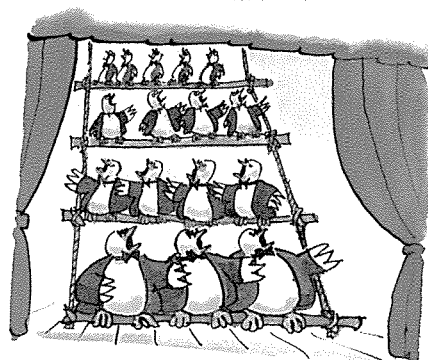
Like humans, birds do have local accents or dialects. Chaffinches are common right across Europe in woods, farms and city parks and gardens. The song of a Scottish chaffinch, even to our poor hearing, is detectably different from a London one, that of a Dutch bird different from a chaffinch spending its life on the French Riviera. The basic form of the song is similar, but variations have grown up as birds from a particular area imitate one another, just as human regional accents developed.



A bronzy hermit (*Glaucis aenea*), feeding in the rainforest of Costa Rica. The male's song pattern alternates between liquid splutters and warbles and high-pitched thin, ready whistles.

TWEET MUSIC

A CHOIR OF CANARIES IN THE UKRAINE HAVE A REPERTOIRE OF MORE THAN 80 CLASSICAL PIECES INCLUDING STRAUSS WALTZES



Paul Raymond

Although most birds sing during the day, others also sing at night, including the nightingales, which have, to our ears, one of the most melodious and varied of all bird songs. Reed warblers sing at night with a purpose. Males arrive in Europe some days earlier than the females from their winter quarters in Africa. During the day, they set about establishing their territory in the reed bed. On calm, clear nights, they climb to the top of a reed stem

bird calls or song by playing either a tape or a bird song record slowed down to one-eighth speed, which brings your ability to hear up to some where near as good as a bird's.

Pitch variations

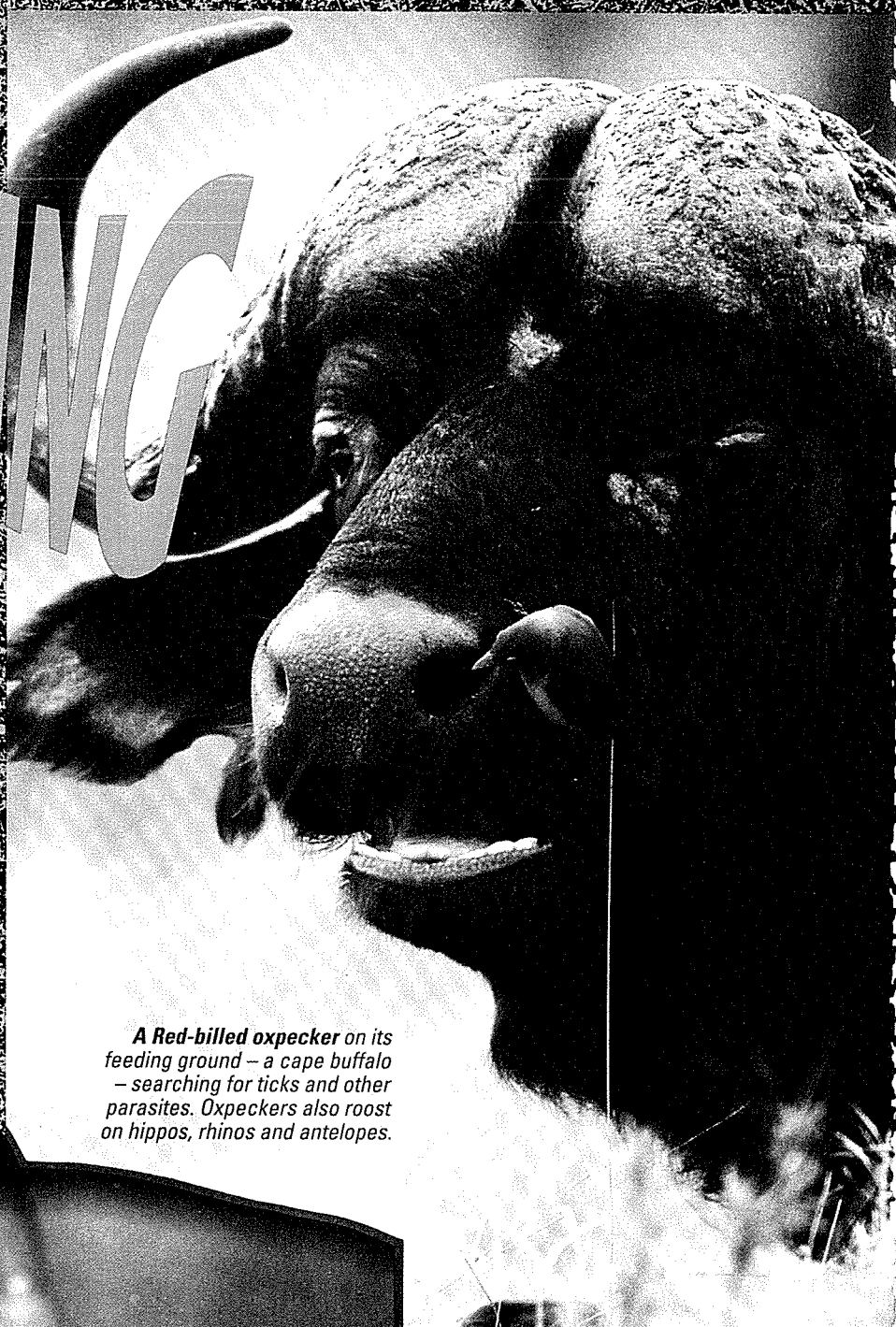
Even simple songs and calls can now be heard to contain complicated changes in pitch and tempo, which allow the bird to produce several quite detailed messages. It seems



- PROBOBOLUS
- PARENTAL CARE
- MIGRATION

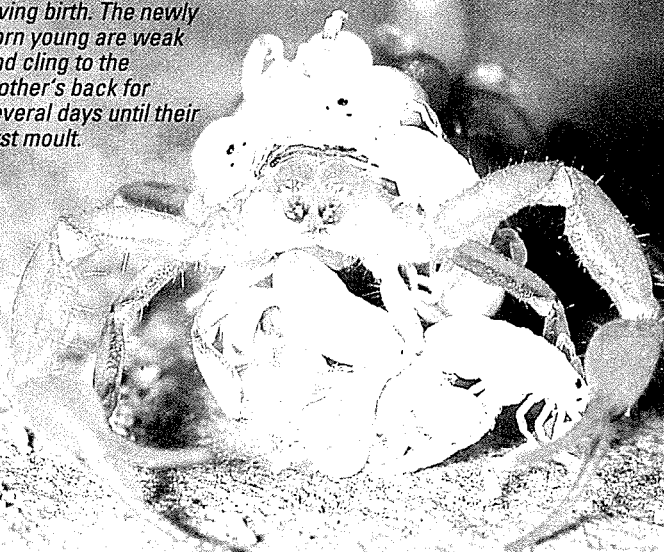
HITCHHIKING

A RIDE



A Red-billed oxpecker on its feeding ground – a cape buffalo – searching for ticks and other parasites. Oxpeckers also roost on hippos, rhinos and antelopes.

A wood scorpion giving birth. The newly born young are weak and cling to the mother's back for several days until their first moult.



SOME ANIMALS AND PLANTS use others as a means of transportation. Birds ride on the backs of cattle. The flatworm *Scotoplanes* lives in the eyes of hippopotamuses. And certain frogs, scorpions and marsupials such as the koala bear carry their young until they can function independently.

● Shark companions

Sometimes this relationship is mutually beneficial. Most sharks from the comparatively docile leopard to the feared great white have a companion fish called a cleaner fish. A cleaner fish was thought simply to be hitchhiking a lift benefiting



also from the scraps as the shark hacked its prey to pieces. Sucker fish hold tight to the rough skin of the shark, even in the frenzy of an attack, using the powerful sucker on their head which is actually a greatly modified dorsal fin. Now it has been discovered that the shark also

The fungus *Pilobolus* that grows on horse dung. This magnification shows the spore capsule – the sporangium.

pass a pile of dung from a horse, give it a closer look. After a couple of days the surface is likely to be covered by a grey hairy mould or fungus, called *Pilobolus*. This travels from place to place inside the horse's gut. It is deposited with the dung and starts to grow. When it is ripe and about to produce spores, *Pilobolus* puts out stiff threads ending in a cell containing a water drop, topped by the microscopic spherical black sporangium. Sunlight playing on this lens of water bursts it, and catapults the sporangium many metres away on to fresh grass. Horses do not graze near their droppings, so if the sporangium is to get eaten and travel again in a horse's gut it must go through this fungal cannonball performance.

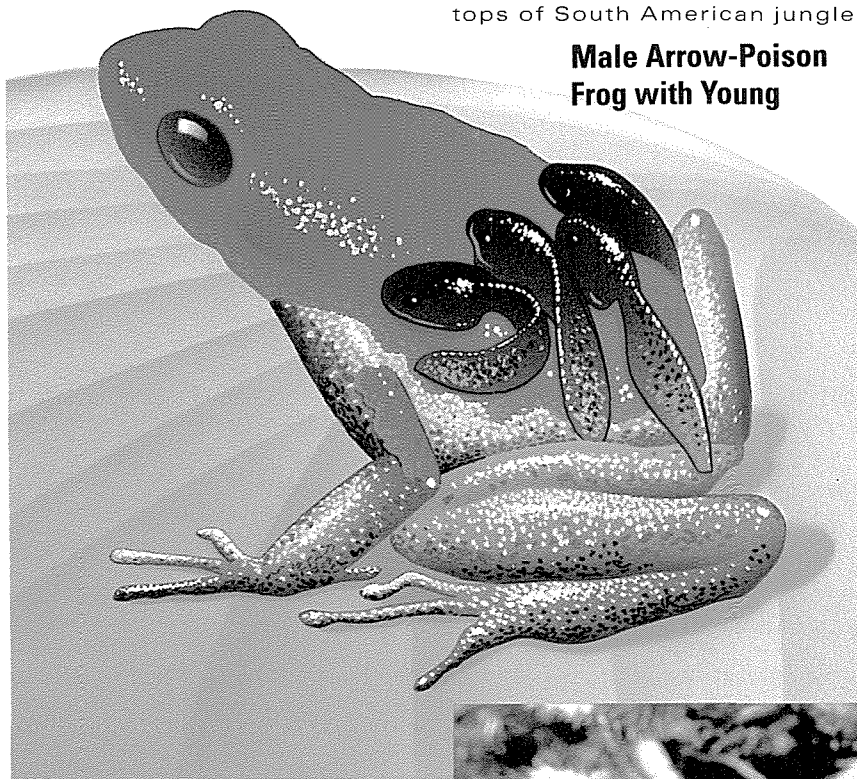
Firing roundworms

What is more startling is that this hitchhiker carries another hitchhiker during its cannonball routine. Horses also have micro-

by *Pilobolus* suits them fine. They wriggle through the dung and slither up the fungus in the film of water that coats it after a heavy dew. When they reach the top of the sporangium, they coil up, waiting to be fired off to pastures new.

Sloths are not the fastest creatures to hitch a lift with. For a start, they spend most of their lives in the tree-tops of South American jungles

Male Arrow-Poison Frog with Young



Two species of male frog transport tadpoles on their backs. In some other species, such as the South American tree frog, the female carries the eggs.

scopic nematode roundworm parasites living in their gut that either share their food or live by sucking blood from the gut wall. Some are damaging to their host, but most cause little harm. To be successful, these parasites need to spread from one horse to another, so hitching a ride on the spore dispersal mechanism evolved



A kangaroo's young – a joey – is only 2.5 centimetres long when born. It stays in the mother's pouch for about six months.

benefits. The sucker fish cleans off and eats the sea-louse parasites that gather on the shark's gills and fins.

Oxpeckers, starling-sized birds often to be seen riding on the backs, necks and legs of African mammals like rhinos and giraffes, do much the same job in exchange for their lifts. Oxpeckers cling on with their sharp claws that give a firm grip on tough skin. With their sharp beaks they prize out eggs or larvae laid in their host's skin by insect parasites. These are their only source of food, so oxpeckers depend on the African mammals for survival. The rhinos and giraffes benefit, not just by the removal of harmful parasites, but also from the sharp eyes of the oxpeckers. On the lookout in all directions, the birds sound the alarm when danger is approaching.

Not all hitch-hikers travel on the outside of their hosts. Next time you

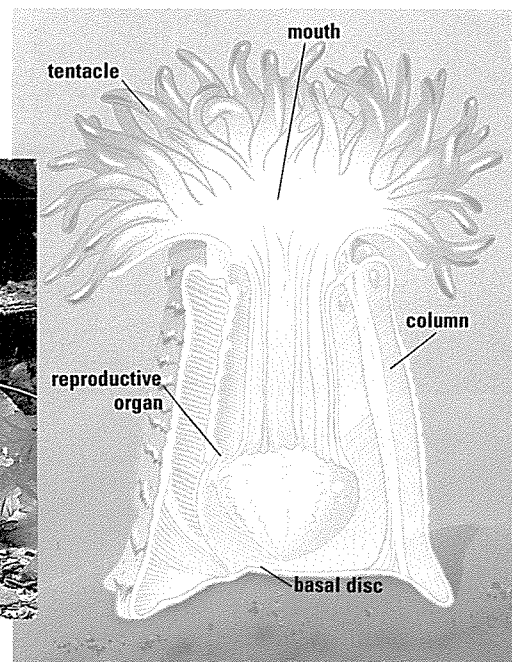
hanging upside down from the branches. Not only do they sleep for 15 hours each day, but they hold the record as the slowest moving mammals. Even though they are the size of a labrador dog, sloths usually lumber along at a steady 1 km/h, but if really pressed, they can accelerate to 2 km/h. Living upside down, their long coarse hair hangs down from a parting along their bellies. They are so slow-moving – and the atmosphere in tropical forests is so humid – that plants like lichens and algae quickly gain a hold and grow on their fur. Being greenish, these hitchhikers may actually help by camouflaging the sloth. Besides being the carrier of small plants, the sloth also transports some animal life as small jungle moths live among the fur.

G.I. Bernard/Oxford Scientific Films



The hermit crab has a soft unprotected abdomen. For security it inserts itself into an empty mollusc shell, leaving only its head and claws outside. The sea anemone (*Calliactis parasitica*)

attaches the base of its body to the shell. In spite of its name the sea anemone is not a parasite as the crab benefits. The relationship is known as commensalism – 'eating at the same table'. The hermit crab is a messy eater so the anemone needs minimum effort



to find food and is provided with access to fresh feeding grounds. The crab benefits from the protection of the anemone's stinging tentacles and the camouflage it provides.

Joe Lawrence

Baby carrier

The eight-metre-long bounding leaps of the red kangaroo are among the most energy-efficient means of locomotion in the animal kingdom. Most of the spring is provided by strong elastic tendons in kangaroos'

The mouth of this female cichlid fish provides sanctuary for its young in moments of danger. There are over 700 species of cichlid fish in Africa and South America. The eggs of some species are taken into the mouth of the female to be incubated without danger from predators and kept there for a short time after hatching.

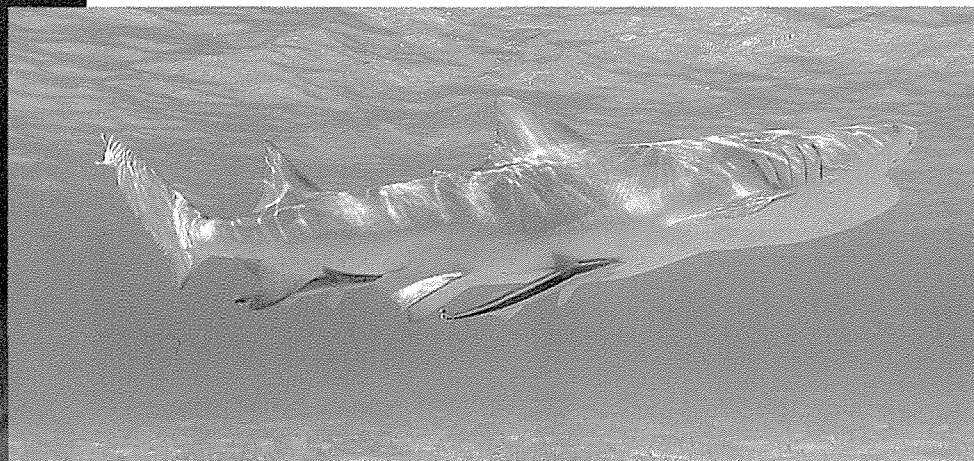
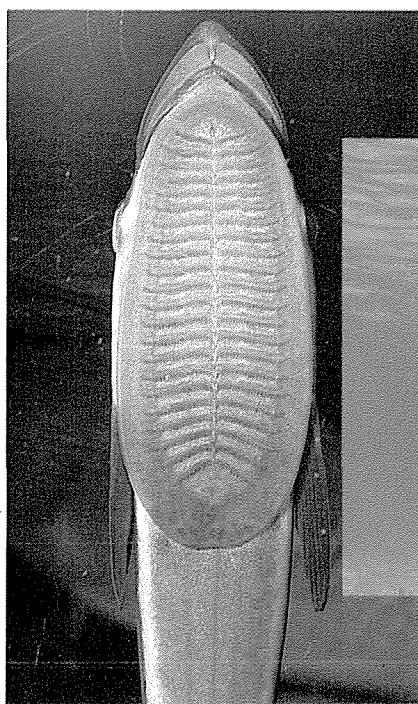
huge hind legs, and only a little by the actual use of muscles. Kangaroos are marsupials, comparatively primitive mammals. They carry their young – a joey – in a pouch on their stomachs.

Although the adult red kangaroo stands almost man-high and weighs around 70 kg, newborn babies weigh only 0.75 g and are no bigger than a jelly baby. Soon after birth, the joey climbs through its mother's fur to the pouch, finds a nipple and hangs on for a feed of rich milk.

Maternal survival

For the next year it will live in her pouch. By then it is big and leggy and often hops in and out to graze on its own. Eventually she refuses to let it back in. Even before the young can survive by itself, should danger threaten, the mother will jettison her joey in order to make her own escape. How-

The oval suction disc of a suckerfish. The sucker is a modified dorsal fin and attaches to the host fish's body (below).

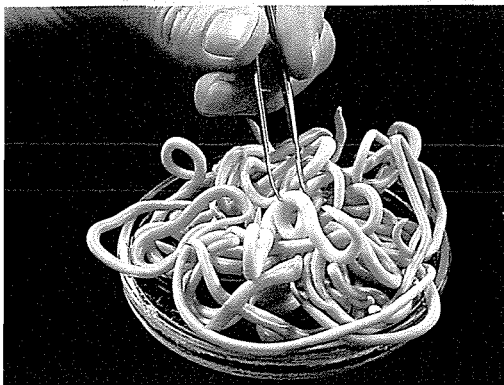


Ken Lucas/Planet Earth Pictures

Doug Perrine/Planet Earth Pictures



PARASITIC WORMS



Nematode worms *Ascaris lumbricoides* are the largest human intestinal parasites – an adult female can be 35 cm long. Infestation with the worms cause vomiting and diarrhoea. Worldwide about 65 million people are infected.

Sinclair Stammers/SPL

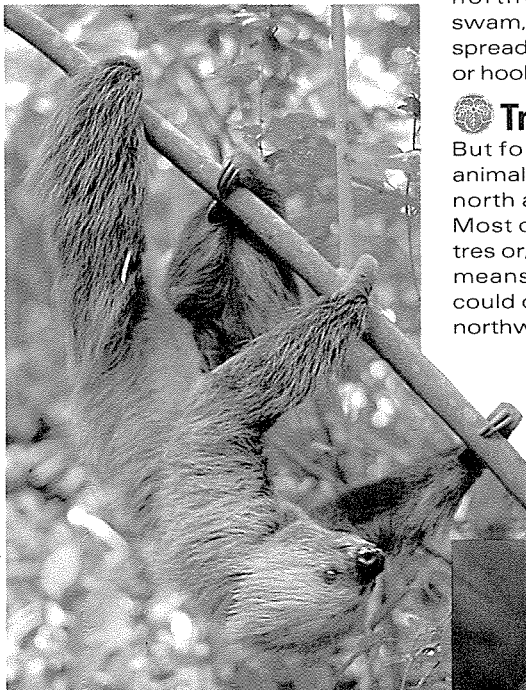
ever brutal this sounds, it means that she will live to produce more young

Male Surinam toads fertilize their female's eggs, then push them into special lidded pouches in the jelly-like skin on her back. They remain in safety in this mobile incubator throughout the tadpole stage until they emerge two or three months later as miniature toads.

The Jack Dempsey cichlid is such

after the eggs are hatched the young feed on their yolk sacs and cannot swim. The male and female Jack Dempsey take their young into their mouths and put them in the pit where they can be watched over and guarded from predators.

Some other species of cichlids carry their eggs, others their young,



Michael Freeman/Bruce Coleman Ltd

Sloth moths live in the algae-covered hair of sloths. The moths lay eggs in the sloth's dung. After the larvae hatches and feeds on the dung the adult moths find a sloth as host.

A carmine bee-eater perched on the back of an Arabian bustard waits to capture the insects – bees, ants, wasps and flies – that the bustard will disturb by its movement over the savannah and dry bush country of Africa. These brilliantly coloured birds, related to the kingfisher family, also prey on locusts.



Lee Lyon/Bruce Coleman Ltd

an aggressive fish that it was named after a former world heavyweight boxing champion. Not only does it fight to defend its territory, but like other cichlids it protects its young in an amazing way. Before mating it builds a pit in the sand. For four days

extremely carefully in their mouths. When it is safe, they blow their young gently out on a current of water to feed, but when danger threatens or they wish to move to fresh feeding grounds, they suck them back in to give them a safe removal service.

Less than 10,000 years ago, during the last Ice Age, much of the northern hemisphere from the North Pole south to the latitude of London was in the grip of sub-zero temperatures and permafrost soil that eliminated all life forms. As the ice cap thawed and retreated, the animals and plants driven south by the cold pressed northward again. Most animals swam, walked or flew, and the plants spread by seeds blowing on the wind or hooked onto the fur of animals.

Travelling north

But for the millions of microscopic animals that live in the earth travelling north again was more of a problem. Most can only move a few centimetres or, at best, a metre in a year. That means since the Ice Age ended they could only have moved about 10 km northwards! No one knows how they managed to recolonize the

northern part of Europe, Asia and America, but it is tempting to speculate that most microscopic soil animals travelled north by hitching lifts on large, more

Ivan Polunin/NHPA

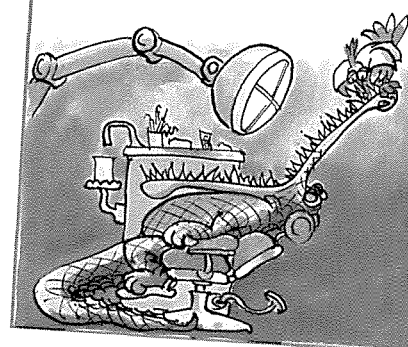


mobile animals. Long-haul migrants like birds cover several hundred kilometres in just a few hours. Animals in the mud on their beaks and feet could survive the journey. The tiny soil creatures would be returned to the ground as soon as the bird landed and started to probe for food.

Just amazing!

DENTAL HYGIENE

THE EGYPTIAN PLOVER BIRD IS REPUTED TO TRAVEL AROUND IN A CROCODILE'S MOUTH AND PICK PARASITES FROM ITS TEETH.



Paul Raymond



DEATH OF THE DINOSAUR

CLIMATE CHANGES • VOLCANIC ACTION • ASTEROID COLLISION



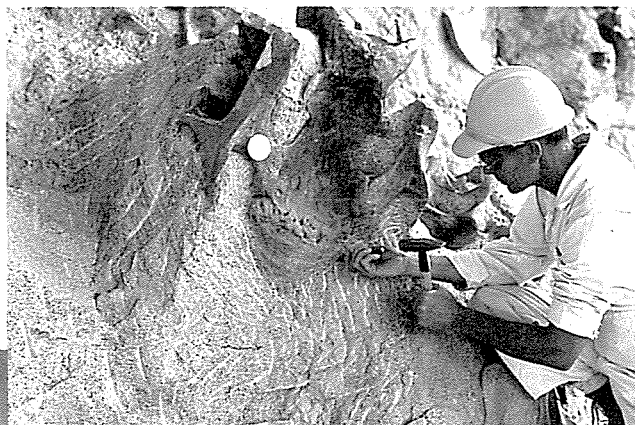
Some scientists believe that a massive asteroid impact caused the dinosaurs' extinction. Others think a volcanic eruption or a gradual climate change was the cause. The debate is still going on.



land-based reptiles that lived during the Mesozoic Era (called 'the age of the reptiles'). What made them different from other reptiles was the fact that, like mammals, their legs were *under* their bodies. This gave them special advantages. They could take longer strides and run faster. Legs positioned under the body like pillars can carry a lot of weight.

Some dinosaurs grew to a tremendous size. Scientists calculate that the Brachiosaurus, perhaps the largest

Dinosaur Nature Association



More dinosaurs can be seen in Utah, USA, than anywhere else. Here, a technician uses an ice pick to relief a vertebra of a sauropod. Utah has the best sauropod skeleton yet found (a Camarasaurus, below left). The plant-eating sauropod dinosaurs are the largest land animals of all time.



Dinosaur Nature Association

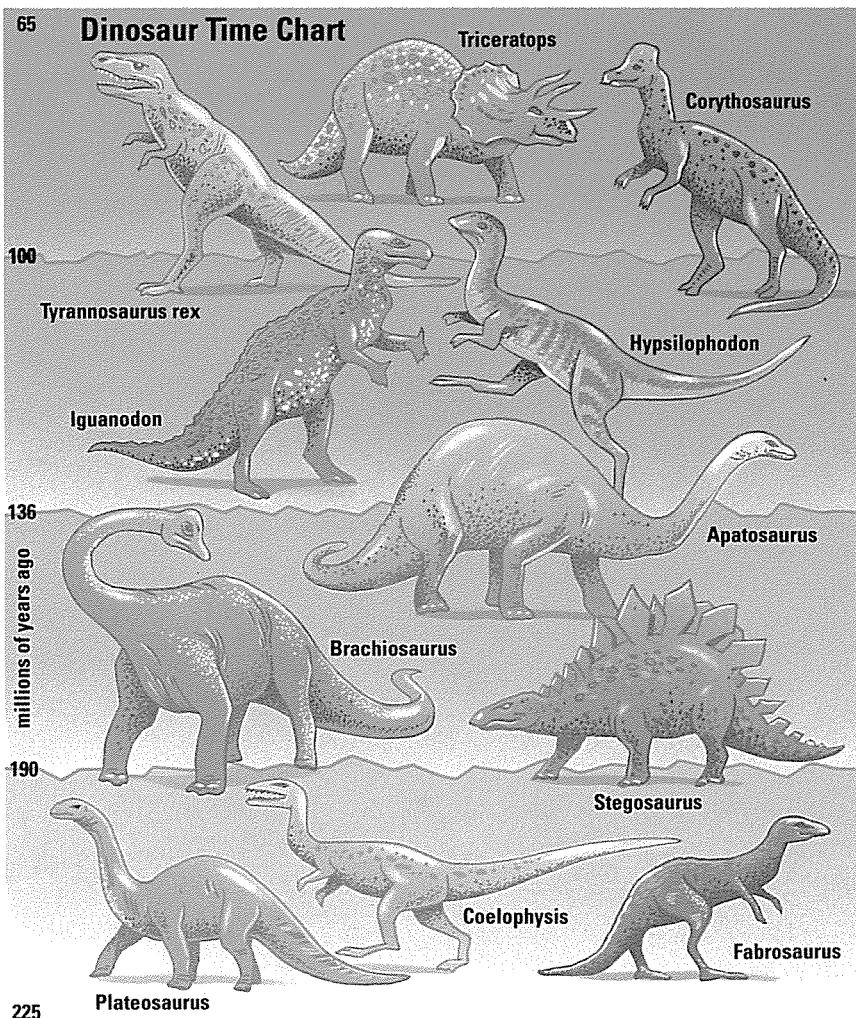
dinosaur of all, weighed 80 tonnes.

At the time the dinosaurs died out, the two early supercontinents Laurasia and Gondwanaland were very slowly splitting into the continents we know today. Volcanic activity, earthquakes and changes in sea-level would all have taken their toll.

Warm or cold-blooded?

The world's climate was also going through major changes and it is very likely that this was a major factor in the dinosaurs' demise. The climate had been very warm and mild, scientists speculate. Then winters became much colder. The effect of this on the dinosaurs would have depended on whether they were cold or warm-

The group of archosaur reptiles known today as dinosaurs lived in the Mesozoic Era. As millions of years passed by, many species evolved, then died out.

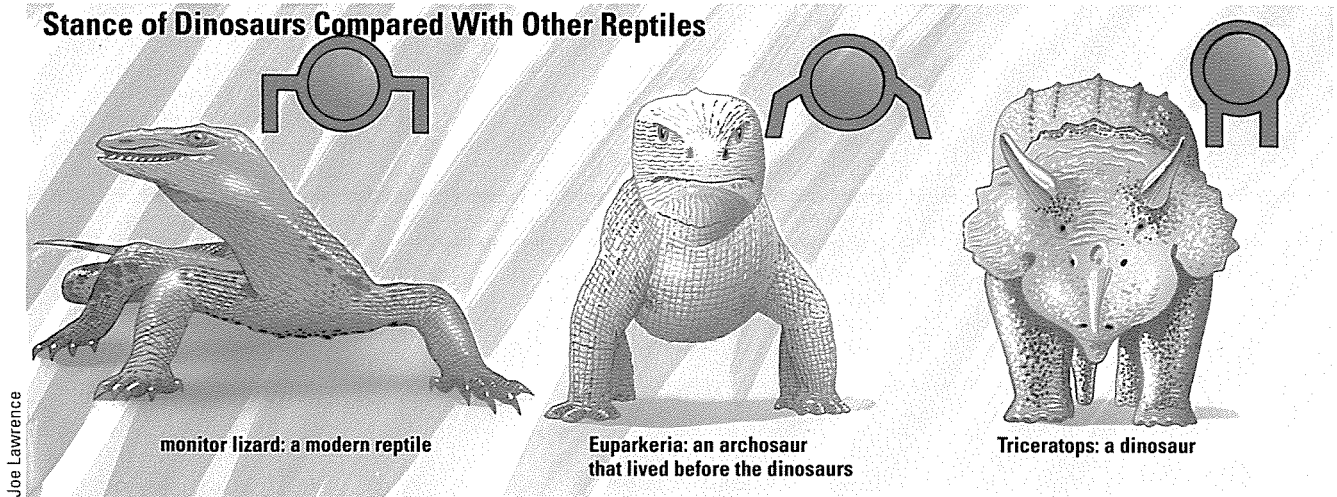


Julian Baum/Science Photo Library

Joe Lawrence

Did an asteroid collide with Earth 65 million years ago and cause the death of all the dinosaurs? Some scientists think so.

Stance of Dinosaurs Compared With Other Reptiles



Joe Lawrence

monitor lizard: a modern reptile

Euparkeria: an archosaur
that lived before the dinosaurs

Triceratops: a dinosaur



J. Cancalesi/Bruce Coleman Ltd

Fossilized eggs of the dinosaur Protoceratops, found in the Gobi Desert in Central Asia. Shown above is a model of a freshly hatched Parasaurolophus. All dinosaurs laid eggs with shells – as do all reptiles.



American Museum of Natural History

blooded. Cold-blooded animals take on the temperature of their surroundings. When it is warm, their metabolism runs fast. When it is cold, their metabolism slows. Warm-blooded creatures, such as mammals, have a built-in temperature regulation control that keeps their temperature – and their metabolism – at the same level whatever the temperature of the outside environment.

**Dying of cold**

It had always been assumed that dinosaurs were cold-blooded like modern reptiles. This would have meant that the colder winters made them more sluggish and inactive, as their metabolism slowed. They would have taken longer to find food and may have slowly starved to death.

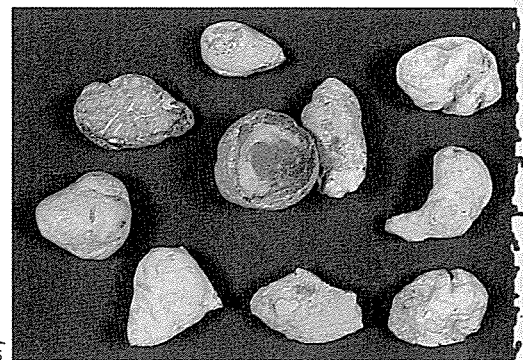
Recently, scientists studying the dinosaur's posture, hunting methods and anatomy have concluded that at least some dinosaurs were warm-

blooded. But they were probably without fur or feathers, and so they still might have died of cold. And they were too large to hibernate.

Why did the colder weather not kill cold-blooded crocodiles? Perhaps because they lived in water, which would have helped maintain a stable body temperature. However, the dinosaurs that lived in the water in swamps did become extinct, together with the giant sea reptiles.

Dinosaurs could move faster than other reptiles because their legs were underneath their bodies rather than sticking out at an angle. A lizard's legs barely lift its body off the ground.

Dr. B. Booth/GSF



Fossilized dinosaur droppings are called coprolites. These are between 195 and 135 million years old.

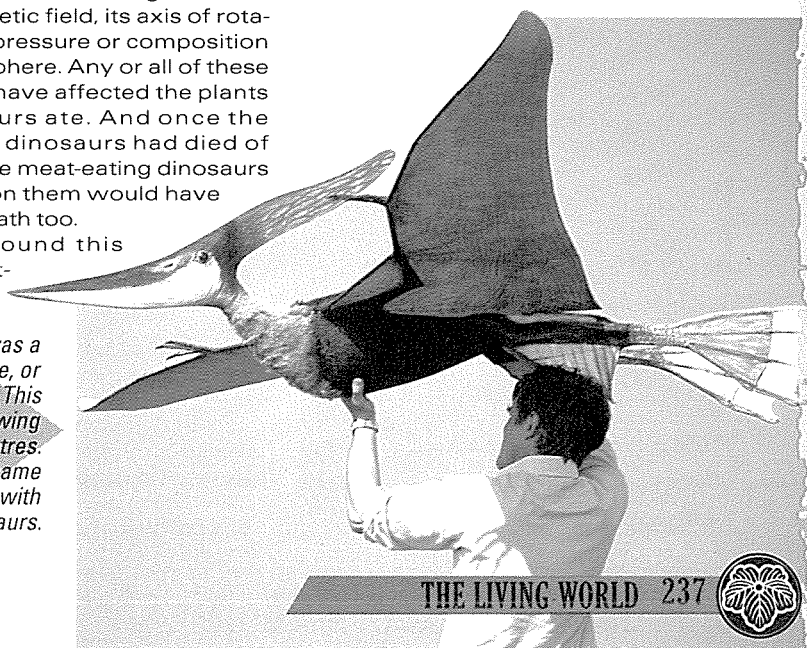
terflies first appeared. One theory states that their caterpillars ate the plants the dinosaurs had been feeding on, so that the dinosaurs starved. Caterpillar numbers would not have been kept down by predators, because birds had not yet evolved. Perhaps the dinosaurs were starved of one source of food, which

Martin Dohrn/SPL

Environmental changes also blamed for the extinction of the dinosaur include increased levels of cosmic radiation, changes in the Earth's magnetic field, its axis of rotation and the pressure or composition of the atmosphere. Any or all of these factors may have affected the plants that dinosaurs ate. And once the plant-eating dinosaurs had died of starvation, the meat-eating dinosaurs that preyed on them would have starved to death too.

It was around this time that but-

Pteranodon was a flying reptile, or pterosaur. This model has a wing span of 4.6 metres. Pterosaurs became extinct along with the dinosaurs.



The impact of such a huge asteroid – speeding into our atmosphere at about 10 km per second – would have triggered devastating storms, fires and acid rain around the world.

Global darkness

Even more importantly, it would have created a huge dust cloud that enveloped the Earth and plunged it into darkness for up to three years. Plants would not have been able to photosynthesize and many would have perished. The

the asteroid – the greenhouse effect.

But where is the crater that such a large asteroid would make on impact? Scientists have calculated that it must be some 150 km in diameter. It may be hidden under the Antarctic ice sheet, or have slipped into a subduction

Frans Lanting/Bruce Coleman Ltd

A Nile crocodile.

Crocodiles are archosaur reptiles, as were the now extinct dinosaurs.

'Dome-shaped' tortoise from the Galapagos Islands.

Turtles are descended from a very early group of reptiles called the anapsids.

Hans Reinhard/Bruce Coleman Ltd



A land iguana, in the Galapagos Islands in the South Pacific. Lizards and snakes form part of the diapsid group of reptiles, which also includes all dinosaurs.

Frans Lanting/Bruce Coleman Ltd

deprived them of a vital part of their diet, such as calcium.

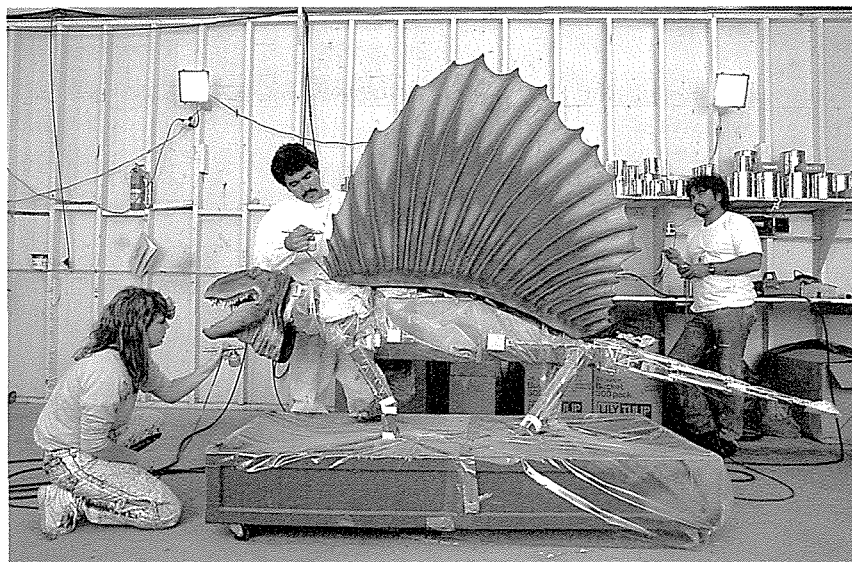
At least one authority says that all this is nonsense. The evidence from fossils indicates that the dinosaurs actually died out over a period of one million years.

Slow death

Even in the few million years before, some species were slowly disappearing and those that remained were confined to a smaller and smaller areas. So there is nothing puzzlingly sudden about their extinction. They simply died out in the natural order of things.

The latest theory is that an asteroid around 10 km across collided with the Earth 65 million years ago.

MODEL DINOSAURS

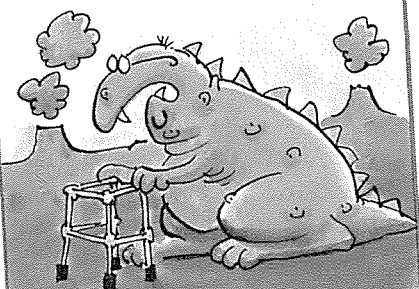


Peter Menzel/Science Photo Library

Just amazing!

SENIOR CITIZENS

DINOSAURS LIVED ON EARTH FOR SOME 155 MILLION YEARS – AT LEAST 80 TIMES LONGER THAN MAN HAS BEEN IN EXISTENCE.



Paul Raymonde

Dinamation International make a very unusual product – robotic dinosaurs. The California-based company's collection of dinosaurs has been exhibited in museums all over the world. Shown above is a *Dimetrodon*, a reptile that actually pre-dated the dinosaurs proper. Its robotic metal skeleton is covered by rigid fibre-glass plates, over which is laid a flexible skin of urethane foam.

The plates and skin are sculpted to appear as accurate and realistic as possible. The creature's joints are operated by compressed air and its movements controlled by a computer. The exhibits are programmed to perform a sequence of movements 3-4 minutes long, accompanied by snarls and roars emitted from speakers hidden inside the model.

food chain would have collapsed and the dinosaurs and many other species would have died from starvation. To make things even worse, this extended winter might have been followed by a period of extreme heat as gases and water vapour thrown into the upper atmosphere by the impact of

zone at the edge of one of the oceanic plates. Tiny glass droplets and 'shocked' quartz crystals created by the impact of an asteroid have been found in Haiti, Jamaica and Cuba in the Caribbean. It may be that remains of the asteroid are under the nearby Yucatan peninsula in Mexico.

